

PROSPECTS FOR CONTINUING U.S. SUPERIORITY IN SPACE:
A SCENARIO-BASED ASSESSMENT

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Military Space Applications and Strategy

by

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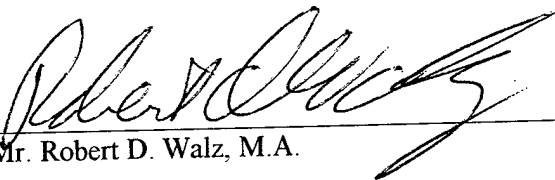
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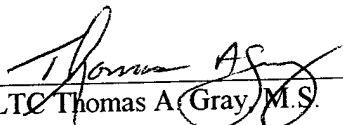
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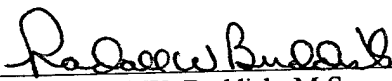
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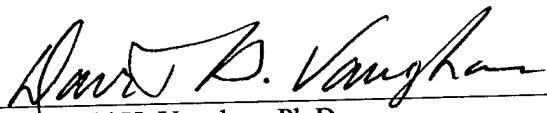
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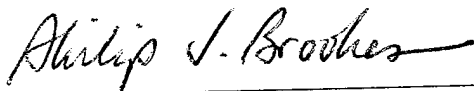
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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

PROSPECTS FOR CONTINUING U.S. SUPERIORITY IN SPACE: A SCENARIO-BASED ASSESSMENT by Major Randall J. Welp, 192 pages.

Joint Vision 2020 prescribes the goal of creating a force for 2020 and beyond that is "dominant across the full-spectrum of military operations." Full-spectrum dominance implies access to, freedom to operate in, all domains, in other words, "superiority" in space, sea, land, air, and information. It has now become apparent that a failure to maintain superiority in space will undermine the ability of U.S. forces to prevail across the full spectrum of future military operations. Therefore, in this research, the viability of space superiority in 2020 is considered. A methodology is constructed that extrapolates current trends, events, and developments to the future in order to evaluate this timely strategic issue. A rigorous scenario development process produced a future environment where commercial space has been relegated to the periphery of the global information infrastructure. Military space is dominant, yet, ironically, the findings presented here indicate this actually threatens the viability of space superiority as a strategic concept.

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LIST OF ABBREVIATIONS

A&I	Acquisition and Integration
ABM	Antiballistic Missile
ACTS	Advanced Communications Technology Satellite
AFRL	Air Force Research Laboratory
ASAT	Antisatellite
ASTRO	Autonomous Space Transporter and Robotic Orbiter
AU	Air University
BAT	Beal Aerospace Technologies
BMD	Ballistic Missile Defense
BMDO	Ballistic Missile Defense Organization
C2	Command and Control
C3	Command, Control, and Communications
C3I	Command, Control, Communications, and Intelligence
C4I2	Command, Control, Communications, Computers, Intelligence, and Interoperability
CBERS	Chinese-Brazilian Earth Resources Satellite
CC&D	Camouflage, Concealment, and Deception
CD	Conference on Disarmament
CNN	Cable News Network
CONUS	Continental United States
COTS	Commercial off the Shelf
DARPA	Defense Advanced Research Programs Agency

DBS	Direct Broadcast Satellite
DCS	Defensive Counter Space
DERA	Defense Evaluation and Research Agency
DIA	Defense Intelligence Agency
DMSP	Defense Meteorological Satellite Program
DoD	Department of Defense
DSCS	Defense Satellite Communications System
DSL	Digital Subscriber Lines
DSP	Defense Support Program
DTH	Direct to Home
ESA	European Space Agency
EU	European Union
FAS	Feasibility, Acceptability, and Suitability
FCC	Federal Communications Commission
GII	Global Information Infrastructure
GIS	Geographic Information Systems
GOES	Geostationary Orbiting Environmental Satellite
GPS	Global Positioning Satellite
I&W	Indications and Warning
ICBM	Intercontinental Ballistic Missile
IO	Information Operations
IOC	Initial Operational Capability
IRAD	Independent Research and Development

ISI	ImageSat International
ISR	Intelligence, Surveillance, and Reconnaissance
ISRO	Indian Space Research Organization
ISS	International Space Station
IT	Information Technology
ITU	International Telecommunications Union
JCS	Joint Chiefs of Staff
<i>JV 2020</i>	<i>Joint Vision 2020</i>
LEO	Low-Earth Orbit
LMI	Lockheed Martin Intersputnik
MEMS	MicroElectroMechanical System
MILSATCOM	Military Satellite Communication
MoD	Ministry of Defense
MTCR	Missile Technology Control Regime
MSI	Multispectral Imagery
NASA	National Air and Space Administration
NATO	North Atlantic Treaty Organization
NII	National Information Infrastructure
OCS	Offensive Counter Space
OICETS	Optical Inter-Orbit Communications Experiment
NDU	National Defense University
NIC	National Intelligence Council
NIMA	National Imagery and Mapping Agency

NMD	National Missile Defense
NOAA	National Oceanic and Atmospheric Administration
NRO	National Reconnaissance Office
NRT	Near-Real Time
PLA	People's Liberation Army
PSLV	Polar Satellite Launch Vehicle
RF	Radio Frequency
RII	Regional Information Infrastructure
RMA	Revolution in Military Affairs
SA	Situational Awareness
SAR	Synthetic Aperture Radar
SES	Societe Europeenne des Satellites
SIA	Satellite Industry Association
SPORT	Small Payload Orbit Transfer
SSA	Space Situational Awareness
SSTL	Surrey Satellite Technologies Ltd
SSTO	Single Stage to Orbit
TMD	Theater Missile Defense
TOS	Tactical Optical Satellite
U.N.	United Nations
UPSI	Universal Payload Secondary Interface
USSPACECOM	United States Space Command
VSAT	Very Small Aperture Terminals

CHAPTER 1

INTRODUCTION

Today, space-based assets transmit a significant portion of the information critical to military operations. It's clear this reliance on space will continue to grow. Traditionally, we've talked about space as a combat multiplier in a combat support role, and that thinking was on target as we attempted to get all the warfighters to think and integrate space. However, now space has become much more basic and intrinsic than just a force multiplier. Space is a prerequisite. It's not a luxury anymore; it's a requirement for conducting military operations. Space has proven itself vital to our national interests.

General Ralph E. Eberhart

Space, without exaggeration, is the foundation for stability in the world.

It is the military space component that raises the effectiveness of modern armed forces. Without this component it is impossible to strengthen the global strategy for stability.

Vladimir Putin

Overview

Joint force commanders recognize that space superiority is essential to the American way of war. Operation DESERT STORM was the first conflict to demonstrate the critical role space plays in expeditionary operations; operations in Kosovo confirmed U.S. reliance on space has only increased since the early 1990's. It is naive to assume future adversaries will continue to concede this ultimate high ground to the United States. Space-based information services are force multipliers. Future adversaries will integrate these services within their force structures and will attempt to deny similar capabilities to the United States. This prediction is based on the military's tendency to "imitate and innovate" that has been repeated throughout history. Consequently, military operations

conducted in and through the medium of space will become as much a part of 21st century conflicts as are those operations conducted on land, at sea, or in the air.

Problem Statement

Joint Vision 2020 (JV 2020) prescribes the goal of creating a force for 2020 and beyond that is “dominant across the full-spectrum of military operations.” U.S. forces, operating unilaterally or in combination with multinational and interagency partners, must be capable of defeating any adversary and controlling any situation across the full range of military operations¹. Full-spectrum dominance implies access to, freedom to operate in, all mediums--space, sea, land, air, and information. Although *JV 2020* singles out information superiority as a key enabler of full-spectrum dominance, it fails to explicitly acknowledge that the expeditionary capabilities of U.S. forces are tied to space-based information services. Failure to maintain superiority in space undermines the ability of U.S. forces to prevail across the full-spectrum of future military operations. The United States has a compelling national security requirement for space superiority, but can space superiority be maintained given the evolving nature of the space medium?

Background

The Cold War space era began with the launch of Sputnik on 4 October 1957; it effectively ended with the dissolution of the Soviet Union on 8 December 1991. For over 34 years, the United States and the Soviet Union each attempted to gain a strategic advantage over the other in space. From landing a man on the moon to developing antisatellite (ASAT) weapons, nearly every aspect of space was an area of competition between the superpowers. While space is still viewed as a medium that can be exploited

for war-fighting advantage, much of the conventional wisdom from the Cold War era no longer applies. Space is now in a state of transition. Yet, it remains to be seen whether or not the environment that is emerging will adversely impact U.S. interests in space. Within this period of change, the United States has chosen to establish a new "way of war." Is the military being prescient or premature in rapidly pushing for this revolution in military affairs (RMA)?

Scope

The premise underlying this research contends that although the United States emerged from the Cold War with space superiority, a "Cold War-centric" model no longer accurately describes the current space environment. As a result, strategies that were valid during the Cold War may be obsolete in the post-Cold War era. Given the increasing role of space in joint operations, it is worth examining this prospect in greater detail.

The preponderance of effort in this research is placed on developing a useful methodology for assessing the viability of space strategy in future environments. This requires two processes--one for constructing plausible future scenarios and one for evaluating strategy within these scenarios. The intent is not to develop strategy; that is a task left as a subject for future research.

In order to test the effectiveness of the methodology, a notional space strategy was required. In keeping with the focus of the thesis, a strategy for space superiority was conceived. Note that table 1 actually presents two strategies for space superiority--one each for the Cold War and post-Cold War time frames. No analytical work was performed using the Cold War strategy; it was provided strictly as a baseline for the

Table 1. A Strategy for Space Superiority

Cold War <i>"Strategic Emphasis"</i>	Post-Cold War <i>"Operational & Tactical Emphasis"</i>
MILITARY OBJECTIVES	
<p>STRATEGIC-LEVEL</p> <ul style="list-style-type: none"> • Detect launch of first strike nuclear attack on United States • Monitor order of battle changes at key military facilities • Detect indications of conventional attack in Europe; Korea • Provide survivable C3I to U.S. strategic forces <p>OPERATIONAL-LEVEL</p> <ul style="list-style-type: none"> • Monitor day-to-day operations of combat-ready forces • Collect imagery data for target development <p>TACTICAL-LEVEL</p> <ul style="list-style-type: none"> • Provide weather data to U.S. forces <p>INTELLIGENCE</p> <ul style="list-style-type: none"> • Collect technical intelligence data <p>SPACE CONTROL</p> <ul style="list-style-type: none"> • Detect, track, and catalog large satellites and space debris • Deter attacks against U.S. satellites 	<p>STRATEGIC-LEVEL</p> <ul style="list-style-type: none"> • Detect launch of first strike nuclear attack on United States • Destroy incoming ballistic missiles launched by rogue nation against United States (limited attack) • Detect indications of conventional attack globally • Provide survivable C3I to U.S. strategic forces <p>OPERATIONAL-LEVEL</p> <ul style="list-style-type: none"> • Provide NRT theater missile warning to deployed forces • Destroy incoming ballistic missiles launched by rogue nation against regional allies (limited attack) • Provide survivable C3I to U.S. expeditionary forces <p>TACTICAL-LEVEL</p> <ul style="list-style-type: none"> • Provide dominant battlefield awareness to theater forces • Provide global, all-weather, day/night, precision targeting data to U.S. forces in NRT • Provide precision navigation signals to U.S. forces • Provide weather data to U.S. forces <p>INTELLIGENCE</p> <ul style="list-style-type: none"> • Collect technical intelligence data <p>SPACE CONTROL</p> <ul style="list-style-type: none"> • Search for small, maneuverable satellites • Detect, track, and catalog satellites and space debris • Rapidly reconstitute satellites and satellite constellations • Protect U.S. satellites from attacks by adversaries • Deny use of space to adversaries through prevention and negation capabilities
MILITARY STRATEGIC CONCEPT	
<ul style="list-style-type: none"> • Maintain survivable, space-based launch detection capability • Maintain survivable, global, near-real time, space-based intelligence collection capabilities • Maintain survivable, space-based communication capabilities • Maintain launch, launch support, and range infrastructure • Maintain a global space surveillance network • Develop and deploy a robust ASAT capability 	<ul style="list-style-type: none"> • Maintain survivable, space-based launch detection capability • Maintain survivable, global, near-real time, space-based intelligence collection capabilities • Maintain survivable, jam-resistant, space-based communication capabilities • Maintain jam-resistant, space-based navigation capabilities • Maintain launch, launch support, and range infrastructure • Develop and deploy offensive space control capabilities • Develop and deploy a launch-on-demand capability • Develop and deploy space- and ground-based space situational awareness sensors • Develop and deploy a constellation of space-based lasers for national missile defense
RESOURCES	
<ul style="list-style-type: none"> • DoD investment in dedicated satellite programs 	<ul style="list-style-type: none"> • DoD investment in dedicated satellite programs • DoD purchase of commercial services • Joint force leveraging of coalition space capabilities • Foreign involvement in DoD space programs (e.g. intelligence, communications, and missile defense) • Civil (NASA; NOAA) investment in programs with military utility • Commercial investment in programs with military utility • University research efforts with military utility

post-Cold War strategy. However, its inclusion should give some indication of how significantly the strategic concept of space superiority has changed over the past decade.

Importance

Space is extremely important to the U.S. military, but will the collective actions of the international community threaten the viability of space superiority as a strategic concept through 2020? The effectiveness of U.S. force modernization strategy hinges, to a great extent, on the answer to this question. The reliance of the U.S. military on space-based information systems continues to increase with each passing year. Yet, the military appears reluctant to make the decisions necessary to ensure superiority in space. Lacking an unambiguous threat, space superiority has received a lower priority than other defense needs. Space superiority is too important to the security of this nation to wait for an unambiguous threat to emerge. The United States faces the very real prospect of a future "Pearl Harbor in space" unless there is a fundamental shift in the way Americans view space power vis-à-vis the rest of the world.

Context

Over the past ten years, space--as an arena of human endeavor--has undergone significant change. Much of the impetus for change can be attributed to the end of the Cold War; however, technological advances have also exerted a profound influence. In the aggregate, these forces have rendered the Cold War space paradigm obsolete. Table 2 summarizes the significant characteristics of space during both the Cold War and post-Cold War time frames. The discussion that follows expands upon these characteristics and provides a brief explanation of how they have evolved since the end of the Cold War.

Table 2. Changing Space Paradigm	
<i>Cold War (1957-1991)</i>	<i>Post-Cold War (1991-Present)</i>
<ul style="list-style-type: none"> • Bipolar Environment • National Programs • Dedicated-Use Capabilities • Services to Institutional Users • “Meeting the Threat of Surprise Attack” 	<ul style="list-style-type: none"> • “Skewed” Multipolar Environment • National, Regional, and Global Consortia • Dual-Use Capabilities • Services to Individual Consumers • “Space as a Force Multiplier”

From Bipolar Environment to “Skewed” Multipolar Environment

The dissolution of the Soviet Union enabled the United States to become the world’s pre-eminent space power. Jim Oberg, a noted expert on the Soviet/Russian space program, summarizes the turn of events as follows:

And, while it is true that America now enjoys a position of space hegemony, it is only as a result of the recent demise of an adversary of equal stature.²

The Russians have acknowledged the sorry state of the remnants from the former Soviet space program--34 out of the 44 Russian civilian satellites in orbit “could break down at any moment.”³ Thus far, no single nation has emerged to replace the Soviet Union as a “near peer” competitor and challenge the United States in space. Since the mid-to-late 1990s, the bipolar environment of the Cold War had been replaced with a skewed multipolar environment--that is, the United States and a handful of “lesser equals.”

From National Programs to National, Regional, and Global Consortia

National space programs were pursued virtually regardless of cost during the Cold War. Driven by defense requirements for strategic command, control, communications,

and intelligence (C3I), along with desires for enhanced international standing, the United States and the Soviet Union each devoted considerable resources to their national space programs. In today's fiscally constrained environment, many nations--the United States included--are looking to partner on important civil and military space projects. Reference the International Space Station (ISS), the French, Spanish, and Italian "Helios-1" reconnaissance satellite, and the Chinese-Brazilian Earth Resources Satellite (CBERS) as evidence of this trend.

The high cost of space also has encouraged the formation of commercial consortia consisting of satellite and earth station manufacturers and national service providers. National, regional, and global consortia provide opportunities such as additional capital financing, spreading of risks, and better access to markets.⁴ Table 3 illustrates that while the number of commercial consortia has exploded, military programs have remained relatively constant.

From Dedicated-Use Capabilities to Dual-Use Capabilities

Satellites are inherently movers, broadcasters, collectors, or generators of information. This, in turn, leads to the notion of satellites as space-based information systems. Table 4 highlights the fact that space-based systems have been developed to provide services on a global scale. When viewed in this manner--and not in terms of "reconnaissance" or "MILSATCOM"--the dual-use aspects of space become apparent. Today, nearly every satellite on orbit could be used for both military and civil applications. Space-based information services have always held potential for dual-use.

Table 3. Space Commercialization--Then and Now							
Cold War (as of Dec 1979) <i>Government Consortia</i>				Post-Cold War (as of Dec 2000) <i>Private & Government Consortia</i>			
Consortium	Date	Own	Type	Consortium	Date	Own	Type
Intelsat	1964	GC	Comm	Intelsat	1964	PC	Comm
Intersputnik	1971	GC	Comm	Intersputnik	1971	PC	Comm
Arabsat	1976	GC	Comm	Arabsat	1976	GC	Comm
Inmarsat	1979	GC	Comm	Inmarsat	1979	PC	Comm
Cold War/Post-Cold War <i>Military Satellite Programs</i> <i>(Representative Satellites--Not All Inclusive)</i>				PanAmSat	1984	Pvt	Comm
				Spot Image	1984	PC	Imaging
				Eutelsat	1985	GC	Comm
U.S.	U.S.	Type		Asiasat	1988	Pvt	Comm
KH-4	"Classified"	Imaging		SES	1989	Pvt	DTH
DSCS I	DSCS III	Comm		Orbcomm	1990	Pvt	Comm
N/A	Milstar	Comm		Iridium	1991	PC	Comm
Transit 5A1	GPS	Nav		Globalstar	1991	PC	Comm
DSP	DSP	Msl Wn		Orbimage	1993	PC	Imaging
DMSP	DMSP	Wx		Space Imaging	1994	PC	Imaging
USSR	Russia	Type		DirecTV	1994	Pvt	DBS
Zenit-2	Yantar-4K	Imaging		EarthWatch	1995	PC	Imaging
Molniya-1	Molniya-3	Comm		New ICO	1995	PC	Comm
Nadezhda	Glomass	Nav		Echostar DishNet	1996	Pvt	DBS
Raduga	Raduga	Comm		ImageSat	1996	PC	Imaging
Oko	Prognoz	Msl Wn		Skybridge	1997	PC	Comm
Comm--Communications DBS--Direct Broadcast Satellite DTH--Direct-to-Home GC--Government Consortia Mil--Military Msl Wn--Missile Warning Nav--Navigation PC--Private Consortia Pvt--Private Wx--Weather <i>Compiled from Multiple Sources</i>							

However, this promise was not realized until the Gulf War. Traffic flow estimates by the Department of Defense (DoD) show that commercial satellites carried more than 22 percent of military wideband communications during Operation DESERT STORM.⁵

Since that time, the United States has increasingly leveraged the capabilities of commercial space systems for military communications, weather, and intelligence. Other nations are choosing to adopt this approach as well.

Table 4. Space-Based Information Systems			
Function	Service	"Dual Use" IOC	Satellites
Communication	To <i>move</i> information	1969 1996	Intelsat II, III Italsat
Communication	To <i>broadcast</i> information	1996	Echostar I
Remote Sensing	To <i>collect</i> information	1986 1999	SPOT Ikonos
Weather	To <i>collect</i> information	1975	GOES
Navigation	To <i>generate</i> information	1995	GPS
Intelsat II, III Second and third series communication satellites operated by Intelsat (Note: No longer in use) Italsat Italian communication satellite Echostar I U.S. direct broadcast satellite SPOT French commercial imaging satellite (10-m resolution) Ikonos U.S. commercial imaging satellite (1-m resolution) GOES U.S. civil weather satellite GPS U.S. military navigation satellite <i>Compiled from Multiple Sources</i>			

From Services to Institutional Users to Services to Individual Consumers

Within the commercial space sector, the emphasis has shifted from serving institutional users--for example, national telecommunications agencies--to meeting the needs of individual consumers. Now, people from all segments of modern society use space-based information services. From pagers to direct-to-home (DTH) TV to navigation displays in automobiles, space-based services are ubiquitous. Rare is the person whose life is not directly affected by one or more of these services on a daily basis.

The strategic shift from institution to individual has far-reaching ramifications for the space industry. Now, the industry is subject to market forces--pure competition is a new experience. Space-based information services must satisfy mass-market consumer demand. Given the length of time required to design, build, launch, and test a new service, it will always be a challenge for a space-based service to be "first to market." Additionally, the harsh environment of space and the basic laws of physics cause disruptions to space-based services that many consumers may find annoying or inconvenient. To date, the results are mixed in terms of the industry's ability to compete under pure free market conditions.

From "Meeting the Threat of Surprise Attack" to "Space as a Force Multiplier"

From the flight of Discoverer XIV in August 1960 to the outbreak of the Gulf War in January 1991, space assets were used to ensure a state of "strategic stability" existed between the superpowers. Satellites monitored missile fields, bomber bases, naval facilities, and troop assembly areas for indications and warning of surprise attack. The principle of "open skies" was accepted by the United States and the Soviet Union as both sides recognized the inherent advantages of transparency.

During Operation DESERT STORM, the United States changed the nature of space as surely as space changed the nature of warfare. General Merrill McPeak, former United States Air Force chief of staff, proclaimed combat operations in the Persian Gulf as "the first space war." Military and commercial space-based information services were used for intelligence, communications, navigation, targeting, and weather forecasting. For the first time in history, space was used as a force multiplier at the operational and

tactical levels of war. As a result, space is now a part of all battlefields at all levels of conflict.

Has the rest of the world adjusted its thinking to this post-Cold War space paradigm? When contrasting the statements of General Eberhard and President Putin cited at the beginning of this chapter; one is struck by two diametrically opposed viewpoints. General Eberhard considers space a “prerequisite” for military operations; President Putin regards it as the “foundation for stability.” How much more difficult it is to understand and accept the concept of “space superiority” when viewed from the Russian perspective.

Research Questions

The primary research question this thesis addresses is whether space superiority is a viable strategic concept through the *JV 2020* time frame. In order to fully answer this question, a number of secondary and tertiary questions are considered.

How foreign militaries are likely to use space in the future is the first crucial dynamic that must be assessed. Recent efforts have centered on obtaining space systems to complement existing C3I capabilities. Many nations are purchasing commercial “turn key” space systems and developing indigenous space programs to satisfy requirements; however, there are significant unknowns associated with how their militaries will employ these newly acquired assets. Access also plays a key role in the military use of space. Can cheap, innovative methods of placing small satellites into orbit “on demand” be developed, allowing more nations to realistically consider the use of space? The last related question concerns whether nations opt to pursue offensive counterspace weapons.

Will militaries be content with using space solely for force enhancement, or will they also see a need to deny its use to adversaries?

Another important area of uncertainty is technology. The National Intelligence Council (NIC) characterizes what is not known about the ongoing technology revolution as “staggering.”⁶ Advances in disciplines essential to future space systems--for example, electronics, propulsion, materials, and nanotechnology--will impact the ability of the United States to maintain space superiority. Will the proliferation of technology enable nations to equal or surpass U.S. space capabilities? The answer depends on the extent to which competitive market forces are allowed to drive the spread of this technology. Concerns over U.S. national security may encourage political efforts to curtail the proliferation of certain key technologies. This leads to another vexing issue: Will export restrictions erode U.S. advantages in aerospace manufacturing and technology?

The next concern to be examined is financing. Much of what happens in space is driven by the availability of venture capital. Conventional wisdom holds commercial interests now dominate the space medium and will launch hundreds of satellites over the next five-to-ten years. However, is this belief well supported by recent events? Several large constellations of commercial communication satellites worth billions of dollars have recently been launched; these endeavors are not turning a profit and are struggling to survive. Given such poor performance, will Wall Street continue to support this level of funding, or will future proposals die due to lack of interest? A lot depends on the niche that satellites are able to fill in national, regional, and global information infrastructures (NIIs, RIIs, and GIIs). The question becomes: Will the role of satellites in emerging NIIs, RIIs, and GIIs create renewed interest and investment in space? If

capital is tight, U.S. companies will look overseas for investors. In fact, this has already occurred; at issue is whether it continues. Does the continuing high cost and risk associated with space drive commercial enterprises to form additional multinational alliances and consortia?

Treaties and conventions governing the use of space also stand to grow in importance as new players enter the medium and begin to assert their "rights." There is resentment among both state and non-state actors over U.S. hegemony in space. Will these groups join together to enact treaties and conventions that erode U.S. advantages in space? Despite its vastness, space is a limited resource in many respects. Some feel the United States has acquired far more than its "fair share" of space resources over the years--e.g. RF spectrum; orbital slots in the geosynchronous belt. Can contentious frequency and orbital slot issues be resolved to the satisfaction of all in the coming years?

The final unknown to be addressed involves international attitudes toward space. Will international public opinion accept weapons in space, or will there be a general call for space to be "demilitarized?" U.S. interest in deploying space-based missile defense and space control technologies has spawned controversy over the impending "weaponization" of space. Historically, the public has accepted the military presence in space because it was seen as means of preventing a surprise nuclear attack--everything else was of secondary importance. Now, with space-based lasers and kinetic kill vehicles being actively pursued, the status quo is about to be upset. An international debate on the acceptability of weapons in space may be forthcoming. How the outcome of such a debate would affect U.S. interests is unknown.

Key Terms

Counterspace. Those offensive and defensive operations conducted by air, land, sea, space, special operations, and information forces with the objective of gaining and maintaining control of activities conducted in or through the space environment.

Dual-Use. A technology or service that can be used for both military and commercial applications.

Force Application. Those operations conducted primarily from space with the objectives of strategic defense and power projection. These operations include defense against ballistic missiles.

Force Enhancement (also known as combat support). Those operations that directly contribute to the combat effectiveness of military forces. Space operations contribute directly to combat effectiveness within several mission areas: surveillance, reconnaissance, navigation, communications, and meteorology.

Global Information Infrastructure (GII). Includes the international complex of broadcast communications, telecommunications, and computers that provide global communications, commerce, media, navigation, and network services between national information infrastructures. A key backbone of the emerging GII is a future network of layered broadband communication satellites.

Information Infrastructure. The complex of sensing, communicating, storing, and computing elements that comprise a defined information network conveying analog and digital voice, data, imagery, and multimedia data.

Information Superiority. The capability to collect, process, and disseminate an uninterrupted flow of information while exploiting or denying an adversary's ability to do the same.

Military Space Forces. Those systems and associated infrastructure which establish space power and are employed by the military to achieve national security objectives. Space forces include space-based systems, ground-based systems for tracking and controlling objects in space and transiting through space, launch systems that deliver space elements, and people who operate, maintain, or support those systems.

Smallsats. Those satellites characterized by masses of less than 500 kg. Smallsats can be further subdivided into *minisats* (100-500 kg), *microsats* (10-100 kg), *nanosats* (1-10 kg), *picosats* (0.1-1 kg), and *femtosats* (<100 g).

Space Control. Operations to assure the friendly use of the space environment while denying its use to the enemy. Achieved through offensive and defensive counterspace carried out to gain and maintain control of activities conducted in or through the space environment.

Space Situational Awareness (SSA). SSA is maintaining the level of awareness necessary to support a decision-makers' need to quickly and accurately discern the impact that actions taken in and through space have on land, sea, air, and space activities.

Space Superiority. That degree of dominance in space of one force over another which permits the conduct of operations by the former and its related land, sea, and air forces at a given time and place without prohibitive interference by the opposing force (DoD Space Policy, 1999).

Space Support. Those space operations that include spacelift, command and control of satellites, and surveillance and deconfliction of systems in space.

Superiority. That degree of dominance that permits friendly land, sea, and air forces to operate at a given time and place without prohibitive interference by the opposing force.

Supremacy. That degree of superiority wherein opposing air and space forces are incapable of effective interference anywhere in a given theater of operations.

Turn-Key System. A total package of equipment, training, and spares sold to a buyer that enables the buyer to operate the system without assistance from the manufacturer. A turn-key system gives a buyer complete operational control over the system and eliminates reliance on--or interference from--external sources.

Limitations

This research effort is limited to English-language sources or translations. Unfortunately, this eliminated a large number of potential sources, particularly in the area of foreign military doctrine pertaining to the use of space. The research also makes very little use of primary source data due to lack of access. Primary source data would have been extremely useful in analyzing the economic (i.e., commercial) aspects of space. Finally, no classified data was used in order to facilitate the preparation and subsequent dissemination of this research. It should be noted, however, that none of the aforementioned limitations are believed to be of a significant nature.

A major portion of the research methodology described in chapter 3 concerns a widely used scenario development process. Small groups of "experts," rather than individuals, are usually more effective at producing scenarios. If this research had been

conducted in a non-academic setting, such an approach would most likely have been utilized.

Delimitations

This thesis restricts military applications of satellites to collecting, generating, processing, and moving information through the *JV 2020* time frame. Many within the military space community will contest this view of space systems solely as information systems. They will argue that the application of force from space will become a reality and that a satellite capable of force application is not an information system. The Ballistic Missile Defense Organization (BMDO) is, in fact, researching the feasibility of developing a constellation of space-based lasers to destroy incoming ballistic missiles. However, such a concept appears to be far-term--that is, beyond 2020--based on even the most optimistic projections.

U.S. space policy, infrastructure, and organization--with the exception of assessing international responses to specific U.S. policy decisions--will not be addressed in this thesis. Although these areas profoundly affect the ability of the United States to maintain space superiority, their inclusion would dilute the focus and alter the intent of this research effort. Furthermore, each area has been the subject of numerous studies, commissions, and reviews. Suffice to say, few opportunities remain here for original thought.

Summary

The United States emerged from the Cold War as the world's pre-eminent space power. Throughout the 1990s, the United States used space to great effect in the Middle

East, Korea, and the Balkans. The advantages derived from space were so convincing that leaders now use words like “prerequisite” and “intrinsic” to illustrate the importance of space in military operations. The past success of space-enabled U.S. military operations has ensured that space will play an even larger role in the future. Space superiority has become a cornerstone of the ongoing revolution in military affairs as described by *Joint Vision 2020* and a host of other DoD publications.

One clearly senses significant unease concerning space. The space environment that many “grew up with” during the Cold War is no more. Yet, one wonders if many of the decisions regarding space that are being made today are based on a model that no longer applies. Have strategic concepts such as space superiority that made sense during the Cold War been scrutinized for their applicability in the future? A new paradigm for space is emerging which, although full of promise, is also full of uncertainty. The main objective of this research, therefore, is to build a methodology capable of evaluating a current strategic concept (e.g., space superiority) in a plausible future environment. Although the findings of such an assessment should prove interesting, the more significant outcome is expected to be the methodology itself. As space continues to mature as an area of responsibility in its own right, the need for such tools--and the space strategists who know how to use them--will become critical.

¹“Joint Vision 2020,” Director for Strategic Plans and Policy, J5; Strategy Division, June 2000 [database on-line]; available from <http://www.dtic.mil/jv2020/jv2020.doc>; Internet; accessed 3 June 2001, 8.

²James Oberg, *Space Power Theory* (Washington D.C.: Government Printing Office, 1999), 148.

³"Russian Satellites in Sorry Shape: Admits Russian Space Agency," *SpaceDaily*, 29 August 2000 [journal on-line]; available from <http://www.spacedaily.com/news/russia-comsats-00d.html>; Internet; accessed 3 June 2001.

⁴Joseph Pelton, Executive Summary, "SATCOM 2005: A Projection of Satcom Services through 2005," Falls Church, VA, Aegis Research Corporation, 2000, 13.

⁵Alan Campen, "Silent Space Warriors," in *The First Information War*, ed. Alan Campen (Fairfax, VA: AFCEA International Press, 1992), 139.

⁶*Global Trends 2015: A Dialogue About the Future With Nongovernment Experts*, John Gannon, Chairman (Washington, D.C.: GPO, 2000), 11.

CHAPTER 2

LITERATURE REVIEW

Introduction

The primary objective of the literature review is to lend a degree of credibility to many of the core beliefs underpinning this research effort. The complex and controversial nature of space superiority warrants such treatment. This review also establishes a context in which to place the future space scenario that emerges from the methodology discussed in chapter 3. One should note that this literature review contains few absolute truths--only the opinions and views of several visionary thinkers. Since an international consensus on the future of space has yet to coalesce, understand that many of these writings reflect attempts to influence the ongoing debate.

Much has been written in recent years regarding the military and commercial potential of space. Given the importance of space to U.S. national security and economic interests, this should come as no surprise. In order to gain an overall appreciation of where people believe space is headed, one must read through numerous reports, white papers, and books covering a wide range of issues. However, this review emphasizes only those writings that provide useful insight into the strategic concept of space superiority. There are two areas where the published body of knowledge is particularly helpful--in envisaging general characteristics of the future space environment and in assessing what is required to achieve space superiority within this future environment.

Characteristics of the Future

The present should form the basis of any attempt to forecast the future. In order to gain an appreciation of how space superiority may be viewed tomorrow, it is reasonable to begin by characterizing how space is seen today. In following this approach, the literature review first considers a contemporary definition of space power. Then, it summarizes the thoughts of several well-respected futurists regarding how both the commercial and military space environments may evolve over the coming years.

Elements of Space Power

In the book *Space Power Theory*, Jim Oberg identifies a set of elements within a nation that enable it to wield "space power." Oberg defines those elements as follows:

Exclusivity of Capabilities. Preserves unique expertise in certain areas.

Economy. Provides government subsidies in order to pioneer new technologies where lack of commercial markets may hinder initial development efforts.

Education. Produces a well-educated citizenry with sufficient numbers of engineers and scientists; keeps the nation on leading edge of space-related technology.

Facilities. Has indigenous manufacturing, launch, and command and control (C2) facilities.

Geography. Possesses launch site with ample downrange safety zones.

Hardware and Other Products. Maintains space vehicles as well as the spare parts and reserves necessary to operate them.

Industry. Funds in-house and applied research; pursues space technology and its applications for business and profit.

Populace. Understands the importance of government funding of space; presents no significant opposition to specific space policies.

Technology. Allows access to national and private laboratories conducting basic and applied research.

Tradition and Intellectual Climate. Supports and appreciates space endeavors, enabling them to endure long-term economic and political variations.

The aforementioned elements are very similar to the key decision factors discussed in chapter 3. There appears to be some consensus here as to what is required for a nation to be considered a “space power.” However, one should continue to refine the criteria in terms of what this means, that is, a nation can be a commercial space power, a military space power, or both. Since the strategy for space superiority outlined in chapter 1 requires the United States to be both a commercial and military space power, a discussion of each environment is in order.

Commercial Space Environment

Commercial space-based information services can be grouped into two categories--communications and remote sensing. Navigation was deliberately omitted because these services are provided free of charge by the Department of Defense’s (DoD) Global Positioning Satellite (GPS). Since navigation services are not subject to market forces, communications and remote sensing are the drivers of commercial space. It therefore becomes imperative that one understands some of the key issues surrounding these areas.

Space-Based Communications

George Gilder, author of *Telecosm: How Infinite Bandwidth will Revolutionize Our World*, is one of the leading visionaries in the field of communications. Looking toward the future, Gilder is bullish on space-based communications. His views are somewhat nonconformist, however, in that he believes that constellations of low-earth orbit (LEO) satellites--rather than geosynchronous satellites--will dominate in the future. Given the financial difficulties encountered by Motorola's Iridium, Loral's Globalstar, and Orbital Science's Orbcomm LEO constellations, this may be surprising to the casual observer. Conventional wisdom holds that the terrestrial wireless infrastructure has become so pervasive that there is no longer a viable market for "global-mobile" voice and data services from LEO satellites. Gilder argues this is not the case, contending that the key error is the assumption of widespread cellular coverage. Citing figures that indicate cell phones reach less than 20 percent of U.S. territory and at least 50 percent of the country will never be economically served by cellular, Gilder foresees a viable market.¹ Providers of space-based communications agree and continue to make servicing the rural consumer's needs a central element of their business plans.

As optimistic as Gilder is about the future of LEO communications satellites, he is correspondingly pessimistic about the future of geosynchronous (GEO) satellites. Gilder anticipates GEO satellites will lose most of their network long-haul communications trade to fiber optics.² He states that for fixed point-to-point communication services, satellites are relevant only where fiber does not reach, that is, from the telephone company's central office switch to the home.³ Gilder believes this so-called "last-mile" link between the consumer and the net is the most lucrative market for satellites. Most

industry analysts concur with this assessment--the future of space-based communications will depend largely upon the ability of satellites to compete effectively with terrestrial solutions to the last-mile problem.

Dr. Joseph Pelton of George Washington University's Space Policy Institute has developed his own thoughts on the digital convergence of information technologies and service-based markets. Pelton's vision--referred to as the "Pelton Merge"--suggests that space and terrestrial transmission media will seamlessly merge together. In the *Satcom 2005* study conducted for Air Force Space Command, Pelton writes that the future is not about trading wireless technology for fiber, but rather merging wireless and fiber in broadband and narrowband applications to provide access, speed, and mobility.⁴ Pelton sees satellites and fiber as reinforcing each other rather than directly competing. He believes satellites can survive on a 5 percent share of the global broadband service market and thrive on 10 percent.⁵

The key point to take away from these authors is that space-based communications are in a state of transition. Satellites are no longer competitive with optical fiber in the long-haul communications market; consequently, they must capture a share of the broadband communications market in order to flourish in the future. If satellites fail to gain a niche in this market, the commercial viability of space-based communications may be in doubt by 2020.

Space-Based Remote Sensing

John Baker and Ray Williamson ponder the consequences of dual-use space-based information services in an article entitled "The Implications of Emerging Satellite Information Technologies for Global Transparency and International Security." During

most of the Cold War, the United States and the Soviet Union enjoyed nearly exclusive access to information on events occurring throughout the world. Now, expanded access to data and information that were previously the exclusive domain of a few national governments is changing the conduct of international affairs.⁶ Baker and Williamson argue the widespread accessibility of computing and communications technologies is contributing to an increased international transparency that diminishes the preeminent role of states in international politics.⁷ They go on to state that space-based information technologies are becoming central drivers of this expanding transparency because their global coverage strongly encourages data and information flows that bypass national boundaries.⁸ If one accepts these assertions of Baker and Williamson, one must concede that some nations may have compelling reasons for developing counterspace capabilities.

It is an oversimplification to believe that the current environment of increased transparency in international affairs has been brought about solely because of the growing availability of high-resolution remote-sensing data from commercial satellites.

Williamson points out that the ability to make use of remote sensing data has been greatly accelerated by the development of geographic information systems (GIS) and image processing and display tools over the last decade.⁹ The growth of computing power and technical expertise within developing countries is also serving to rapidly reduce previous barriers to the use of space-based remote-sensing data for monitoring activities in neighboring countries or regions.¹⁰ Thus, as the sources of remote sensing data increase, the ability of lesser-developed nations to make use of this data is increasing as well.

While it is becoming easier to use remote sensing data for commercial applications, the ability to extract information having military utility from commercial

systems will vary considerably from country to country. According to Baker and Williamson, foreign militaries generally lack the doctrine, organization, and weapon systems needed to extract major military advantage from having access to these dual-use sources.¹¹ They go on to argue that access to data is only the first step in a larger process for extracting combat advantage from these information sources. Only a few countries have excelled in the systems integration skills required to match up advanced military information capabilities with weapons delivery platforms.¹²

Notwithstanding the technical difficulties associated with integrating information capabilities with weapon systems, nations remain concerned with the availability of high-resolution space-based imagery. Numerous policies have been implemented to prevent militarily useful satellite data from being exploited by countries or groups with hostile intentions. Most of these efforts involve attempts to control the dissemination (i.e., “shutter control”) of high-resolution space-based imagery. However, Baker and Williamson correctly point out that any regulatory attempts to discourage the use of these data for military and intelligence purposes will be complicated by the difficulty of separating potentially aggressive uses of space-based imagery from legitimate defensive needs for timely information on activities beyond the countries’ boundaries.¹³ Such policies for restricting the satellite imaging operations not only run counter to the idea of nondiscriminatory access to data, but could be difficult to implement if the number of civilian and commercial remote sensing systems grows as projected.¹⁴ Gaining consensus in this area--given conflicting interests among nations--remains a difficult proposition at best.

Military Environment

Military forces figure to become more and more dependent on space through 2020. Militaries will rely on dual-use commercial services and dedicated military services to enhance their capabilities. At the same time, militaries will be looking to deny the use of space-based capabilities to their adversaries. This section examines two components of the burgeoning military space environment--force enhancement and space control. Admiral William Owens, former Vice Chairman of the Joint Chiefs of Staff (JCS), outlines his ideas concerning how space-based information capabilities can be used to enhance military effectiveness. Then, the concept of space control is discussed. The purpose here is to introduce principles, for example, use of space and denial of use, that form the basis of the space superiority concept.

Force Enhancement

In his former capacity as Vice Chairman of the Joint Chiefs of Staff, Admiral William Owens was responsible for leading the Joint Requirements Oversight Council (JROC). This experience lends credibility to his vision of future warfare described in *Lifting the Fog of War*. Admiral Owens uses a system of systems model to illustrate the transformation now occurring within the U.S. military. First, commanders must see the battlespace. Then, they must be able to communicate that battlespace knowledge to combat forces that can use it. Finally, commanders must dominate the battlespace by employing precision force. Central to Admiral Owens' construct is space. He believes that space remains the key strategic environment for winning the current revolution in military affairs (RMA) against any enemy.¹⁵ It is worthwhile to consider each of these

three elements in more detail to understand how Admiral Owens envisions space being employed in future conflicts.

Seeing the Battlespace. Admiral Owens believes that the ability to achieve “integrated sight” holds the strongest potential for U.S. military superiority in the information age.¹⁶ The Admiral defines “integrated sight” as that stage where raw data gathered from a network of sensors of different types is successfully melded into information.¹⁷ While other nations have surveillance satellites and aircraft can outfit these platforms with electromagnetic and acoustical sensors, Admiral Owens maintains that only the U.S. has the ability in the near term to build a global, integrated network of sensors and communications.¹⁸

Admiral Owens also understands the strengths and weaknesses of space-based sensors. He observes that due to the tremendous costs associated with building and launching satellites, there are significant limitations to space-based surveillance in terms of how much information it provides and how precise, accurate, and timely that information is. For example, he points out that it is not yet possible to collect all the electromagnetic emissions continuously from any given area 200 miles by 200 miles (roughly the size of the Kuwaiti theater of operations) on the earth’s surface.¹⁹ Admiral Owens recommends several changes to intelligence, surveillance, and reconnaissance (ISR) concepts of operation as a means of partially overcoming some of these shortfalls. However, to truly achieve the type of continuous coverage Admiral Owens advocates, constellations of satellites will be required.

Communicating Dominant Battlespace Knowledge. From Admiral Owens’ perspective on the JCS, the U.S. military operates a collection of very heterogeneous

military communications systems. Admiral Owens believes these "legacy" communication systems maintained by the services are the most important technical barrier to better joint operations.²⁰ He outlines a requirement for a new digital communications "system of systems" that will provide voice, data, and video (i.e., broadband) communications throughout the operational chain of command. Recall from the earlier discussion on space-based communications that commercial industry is moving in exactly the same direction. Thus, when Admiral Owens states that the U.S. military of the twenty-first century will increasingly rely on civilian networks to handle much of its operational communications needs,²¹ his assertion is based upon emerging realities.

Precision Force and the Commander's Intent. According to Admiral Owens, the ability of the U.S. to bring force to bear faster, over greater distances, with precision and accuracy, is what distinguishes the U.S. military from that of other nations.²² In terms of precision force, space provides the technological key. Admiral Owens believes the NAVSTAR GPS is central to the "smart" war of the present and is likely to be even more important in the future. He envisions a future where the U.S. will be capable of applying force with near-perfect accuracy and precision--within approximately one meter of a target's actual location.²³ Admiral Owens contends that this increase in accuracy alone will significantly change the way Americans think about combat and wage war.²⁴

Without question, space is crucial to the future vision of warfare set forth by Admiral Owens. Space-based high-resolution imagery, broadband communications, and navigation were identified as being the primary enablers of this RMA. In an ideal world, only the U.S. and its allies would have access to these advanced technologies and

information services. In the real world, they are--or soon will be--available commercially from multinational consortiums beholden to no one particular government. Given the significant military advantages derived from the use of space, it logically follows that nations must develop counterspace capabilities that will deny these same advantages to its adversaries.

Space Control

In *Space Power Theory*, Jim Oberg presents several interesting thoughts on the future of space warfare. Oberg first contemplates the feasibility of deploying weapons in space. Given an international environment comprised of global trade organizations, multinational coalitions, and cooperative United Nations (U.N.) security relations, it may be politically indefensible for the world's lone superpower to unilaterally extend the boundaries of warfare into space.²⁵ Oberg surmises that the means by which the placement of space-based weapons will likely occur is under ballistic missile defense, rather than space control.²⁶ The defensive nature of a ballistic missile killer is not the only facet of such a system--it also has inherent offensive capability against satellites.

Acknowledging the growing importance of commercial space, Oberg asserts that the organization most likely to influence the politics for space sanctity is not governmental, but corporate.²⁷ As ownership within the space industry becomes increasingly multinational in nature, servicing a global customer base, one nation's pursuit or protection of gain loses relevance. Consequently, the first instance of warfare in space may be an act of desperation on the part of a rogue nation, rather than the deliberate employment of counterspace technologies by a space-faring nation.

Many people may not realize that the United States fielded an operational antisatellite (ASAT) weapon in the mid-1960s. Lieutenant Colonel Clayton Chun reviews the history of this program in his paper entitled "Shooting Down a 'Star': Program 437, the U.S. Nuclear ASAT System and Present-Day Copycat Killers." This work is extremely relevant because it highlights the fact that an ASAT system does not need to be a highly sophisticated piece of equipment in order to become an effective space denial weapon. Program 437 was based on 1950's technology. Today, equivalent, if not superior, technology is widely available.²⁸ In fact, Lieutenant Colonel Chun points out that several nations--Russia, North Korea, India, and the People's Republic of China--likely possess the capability to replicate Program 437.²⁹

"Shooting Down a 'Star'" allows one to draw several interesting parallels between the current political climate and that of early-to-mid 1960s. A fact lost on those present-day protestors decrying the "militarization" of space is that the United States and the Soviet Union were prepared to fight a war in space less than ten years after the launch of Sputnik. On 17 September 1964, President Johnson announced that the U.S. had developed an ASAT capability to intercept a satellite that might be carrying a weapon that threatened U.S. national security.³⁰ In light of DoD's current emphasis on space, it is also worth noting that by 1965, Congress was chastising the Air Force for not doing enough in the space defense arena.³¹

Plans for the Future

The objective of the literature review to this point has been to develop a conceptual feel for the nature of the space environment. Next, it becomes necessary to examine alternative approaches for dealing with the environment. How the U.S. chooses

to view space doctrinally determines priorities. Priorities, in turn, drive the programmatic decisions the nation makes with respect to a particular environment. Programmatic decisions should provide the means needed to shape the environment, enabling ways that result in acceptable ends.

Doctrine

In the treatise *On Space Warfare: A Space Power Doctrine*, Lieutenant Colonel David Lupton describes four schools of space doctrine. Each school or belief structure is based upon a distinct set of assumptions. Accordingly, each school drives a unique strategic concept for space superiority. The following synopses of each of the four schools should highlight where key differences lay and allow one reflect upon the ramifications for space superiority.

Sanctuary School. The sanctuary school holds that the primary value of space forces is their capability to “see” within the boundaries of sovereign states.³² Advocates of the sanctuary would argue that without the ability to monitor through “open skies,” prospects for attack warning and future arms control treaties would be dim. Continuing with this argument, they contend that overflight is a right that nations have not attempted to deny and that any proposed military use of space must be weighed against the possible loss of peaceful overflight.³³ To supporters of this school of thought, the only way to maintain the legal overflight characteristic is to designate space as a war-free sanctuary. Obviously, any development of ASAT weapons would be a clear violation of this doctrine.

Survivability School. Proponents of the survivability school believe that space systems are inherently less survivable than terrestrial forces. Therefore, space forces

must not be relied upon to provide critical functions, such as communication and weather data gathering, during wartime. The key tenet of this school is that the only defense is to hold the enemy's space forces at risk. Each side holds the opponent's space forces hostage and "must not let the value of the hostages or the capability to take hostages become too unequal."³⁴

"High Ground" School. Those who follow the high ground belief structure maintain that the current strategy of nuclear deterrence is seriously flawed.³⁵ High ground advocates contend deterrence should be replaced by assured survival--a strategy that relies upon an effective space-based ballistic missile defense (BMD) system. Backers of the high ground school see the nation's military center of gravity moving to space and also believe that war's focus will move to space. They argue that the global presence characteristics of space forces, combined with either directed-energy or high-velocity-impact space weapons, provide opportunities for radical new national strategies.³⁶

Control School. The key tenet of the control school is that the primary function of space war is to ensure friendly terrestrial forces have access to the benefits of space and that enemy forces are denied those benefits. Backers of this school view space warfare as being very similar to air warfare. The first objective is to establish some measure of control over the environment. This might be done on an as-needed, where-needed basis, or on an ultimate control (i.e., space superiority) basis.³⁷ Once control is established, the weight of the effort is shifted to support terrestrial forces. Advocates of the control school insist that the capability to deter war is enhanced by the ability to control space. They see space control as coequal with air and sea control in future wars.³⁸

Lieutenant Colonel Lupton argues that the best way to employ space forces is according to the control doctrine.³⁹ While the U.S. has seemingly vacillated from school to school over the last forty-plus years, it may be that U.S. space strategy contains elements of each. One school may be unable to adequately describe the complexities of the space. However, for the purposes of this research, the control doctrine will be used in order to develop the strategic concept of space superiority. Through the year 2020, this is the doctrine most likely applicable to the projected space environment.

Programmatics

Studies, such as the Defense Science Board's *Report on Space Superiority* and the United States Space Command (USSPACECOM), are significant efforts intended to support the planning process for military space. The *Report on Space Superiority* provides a baseline of current capabilities that allows the U.S. to claim superiority in space. The *Long Range Plan* looks into the future and lays out an investment plan that will enable the nation to maintain that superiority.

The Defense Science Board's *Report on Space Superiority* asserts that the United States currently possesses space superiority as a result of the following elements:

1. Global, near real-time, ISR collection capabilities over denied areas and an ability to disseminate that information to users.
2. Effective capabilities in space for indications and warning (I&W), attack assessment, C3, navigation, environmental monitoring, and weather reporting.
3. A unique, worldwide, terrestrially based, space-surveillance capability to detect, track, and catalog multiple objects in space.
4. Space launch and support infrastructure.

5. Capable, high-quality, and responsive space industry.
6. Dedicated C2 organization and infrastructure to exploit, support, and operate space systems for military operations.
7. Government, industry, laboratory, and academic technology along with a skilled manpower base.
8. Constructive relationships with allies and coalition partners that allow augmentation of U.S. space systems and capabilities.

Note that the strategy for space superiority found in chapter 1 (table 1) is based on many of the aforementioned elements.

USSPACECOM has a "Vision for 2020" that emphasizes the U.S. must be capable of continuing this dominance over the space dimension of military operations. However, merely stating that the U.S. needs to do something, for example, "dominate the space dimension," does not make it so. USSPACECOM subsequently developed a *Long Range Plan (LRP)* to integrate military space planning in order to achieve its vision. While the *LRP* was a much-needed first step, it fails to consider how external events might preclude the U.S. from ever attaining the vision. Specifically, the *LRP* does not account for the fact that the actions of other nations will have an impact on the ability of the U.S. to maintain space superiority.

A critical question with significant ramifications for the U.S. remains unanswered in these studies: How will other nations--individually and collectively--attempt to improve their access to space vis-à-vis the U.S.? If this question is not satisfactorily addressed, can the U.S. have confidence that the decisions it is making in space are the right ones?

Forecasting the Future

In this final section of the literature review, the views of leading futurists are considered. In *War and Anti-War*, Alvin and Heidi Toffler assess military space within the hypothetical context of future warfare. The observations of several senior-ranking Chinese military thinkers on the future of space warfare are presented in *Chinese Views of Future Warfare*, edited by Michael Pillsbury. Finally, the section concludes with a summary of several “alternative space futures” scenarios developed by the United States Air Force’s Air University. These scenarios should provide a useful context for assessing the 2020 scenario developed in chapter 5 of this research effort.

Views on Space Warfare

In *War and Anti-War*, Alvin and Heidi Toffler raise several interesting points about the future space environment. First, the Tofflers have discerned a widening split between “space powers” and “nonspace powers.” Those nations falling into the latter category are collectively asserting that space belongs to everyone and that the benefits of peaceful space activity are the “common heritage” of humanity.⁴⁰ Some of the more radical nonspace powers have gone so far as to suggest setting up a U.N. Space Agency to control space activities and redistribute the benefits of space.⁴¹ According to the Tofflers, battles for the control of space for civilian use will intensify in parallel with the exploitation of space for military purposes. In this case, the Tofflers’ prediction (made in 1993) has proven prescient. The Russians and Chinese were quite active at the U.N. in 2000 with their efforts to raise international support for the peaceful use and “demilitarization” of space--clearly a reaction to U.S. intentions to eventually develop a space-based ballistic missile defense shield.

Second, the Tofflers anticipated that pressure for a missile defense system would mount as missiles capable of carrying nuclear, chemical, and biological weapons multiplied. While nothing is particularly profound about the previous statement, the Tofflers recognized a far less obvious point about missile defense. That is, there exists a linkage between space-based missile defense and antisatellite weapons.⁴² The Tofflers were correct in observing that a debate over antimissile defense systems would refocus attention on antisatellite weapons. In the United States, this debate is long overdue; its outcome will have major implications for the ability of the United States to maintain space superiority.

Given the Chinese position at the U.N. and other international forum supporting only the "peaceful use" of space, it is extremely insightful to read what this potential peer competitor has to say about the military's future in space. In an article entitled "Weapons of the 21st Century," Chang Mengxiong writes that since C3I systems are so critical to "information-intensified" weapons and military units, attacking and protecting satellites that are an integral part of the system will become important forms of combat.⁴³ Major General Zheng Shenxia and Senior Colonel Zhang Changzhi describe outer space as a "battlefield of monitoring" in "The Military Revolution in Air Power." These officers view space as essential in providing reliable information with the assistance of reconnaissance, communication, navigation, orientation systems and early-warning systems.⁴⁴ Finally, in "The Third Military Revolution." Chen Huan foresees a continuous stream of "new-concept" weapons that will make outer space the "fifth dimension operational space."⁴⁵ Chen goes on to recite a list of potential weapons--for example, lasers, electromagnetic guns, plasma weapons, and ultrahigh frequency weapons--that

could be used in space. Chen envisions these new-concept weapons as being space based. In the future, he believes both sides will focus on offensive and defense operations conducted from platforms in outer space.⁴⁶

Public rhetoric to the contrary, the Chinese are, at the very least, thinking about future war in space. The Chinese recognize the advantage of space in military operations and understand the importance of denying that advantage to their adversaries. Without question, the Chinese are not alone in this belief. Consequently, it seems apparent from the literature that any strategy for space superiority must include a counterspace component.

Scenarios

Strategic planners commonly use scenarios in their efforts to anticipate the future. Therefore, it should come as no surprise that the scenario-learning methodology employed in this research effort has been tried before. In June 1994, Air University (AU) published a series of eight future space scenarios under the *Spacecast 2020* cover, the result of a one-year effort directed by the chief of staff of the Air Force. The purpose in briefly summarizing five of the eight AU scenarios here is to provide a context for gauging where the 2020 scenario developed in this research would fall within a range of alternative futures.

Spacecast 2020 World. This scenario predicts a multipolar world order, with states loosely organized into regional confederations. In the Spacecast 2020 world, economic security is more important than military security. Trade agreements will become increasingly more important than state-to-state military alliances and treaties. Rich countries are not likely to invest in military space unless there is an economic

benefit as well. Space investment for national security will need to have commercial applications to be viable. Consequently, militaries will cooperate with and rely upon the private sector to provide more or most of its space capability for computing, communications, navigation, weather, and earth resources sensing. Directed energy weapons that can permanently or temporarily disable satellite functions will probably be the preferred ASAT technology for wealthy nations.

Spacefaring World. In the spacefaring world, there are many actors with a strong desire to be involved in space. Advances in communications and information interconnectivity are shared with the inhabitants of each continent. The Earth has become a highly interdependent global village. In this scenario, the militarization of space is limited.

Rogue World. In this scenario, more than one rogue state has developed reliable indigenous spacelift, demonstrated an ASAT capability, and shown a willingness to violate space law. There is a general lack of cooperation concerning the spread of scientific knowledge. This world has limited or little advanced propulsion; spacelift tends to be government dominated. The overall weakness in commercial activity is related to the high cost of lift.

Mad Max, Incorporated, World. This scenario is characterized by many actors with a strong desire to be in space, but are limited by very low technological and economic vitality. In the Mad Max, Incorporated, world, the dominant actors are corporate rather than political. Multinational corporations have taken over many tasks formerly provided by the public sector. Development in space is constrained by a

complex international regulatory environment. The space environment in this world has a commercial focus, with military activity decreasing.

Space Barons World. In this world, few nations have a strong desire to operate in space. Individual entrepreneurs involved in space--so-called "space barons"--have filled the gap left by governments. Thus, the level of government activity will be low; the level of commercial activity will be moderate. High-technological alternate terrestrial options, such as fiber optics, slowed the drive to develop advanced space systems. Political, economic, and social activity relevant to space is inconsistent and lacks focus. Military and civilian dual-use activities and projects are important for conserving limited financial resources.

The Spacecast 2020 team believed that the Spacecast 2020 worldview captured the most likely environment for future U.S. activity related to space. However, in the seven years that have passed since the AU study was completed, much has changed regarding the space environment. Would the team draw the same conclusion today? The point is not to criticize the Spacecast scenarios; rather, it is to highlight the perishability of the assumptions that went in to the scenario development. In scenario learning, the key is process, not product.

Summary

The literature review should leave one with a sense of the complexity associated with space superiority. Much of this complexity stems from uncertainty surrounding the commercial and military space environments. For example, in the mid-1990s, most of the literature was filled with optimistic projections of how over fifteen hundred new satellites would be launched into orbit by 2005. Now, commercial space is struggling to

find itself. The military saw--still sees--tremendous potential for space, but flat or declining budgets have resulted in cancelled programs and drawn out schedules. At some point, some degree of stability must be achieved. This suggests an overall strategy for space superiority is required.

¹George Gilder, *Telecosm: How Infinite Bandwidth Will Revolutionize Our World* (New York: The Free Press, 2000), 101.

²*Ibid.*, 102.

³*Ibid.*

⁴Joseph Pelton, "SATCOM 2005: A Projection of Satcom Services through 2005" (Falls Church, VA: Aegis Research Corporation, 2000, typewritten), 2.

⁵*Ibid.*, 10.

⁶John Baker and Ray Williamson, "The Implications of Emerging Satellite Information Technologies for Global Transparency and International Security," in *Power and Conflict in the Age of Transparency*, ed. Bernard Finel and Kristin Lord (New York: Palgrave, 2000), 239.

⁷*Ibid.*, 222.

⁸*Ibid.*

⁹*Ibid.*, 227.

¹⁰*Ibid.*, 234.

¹¹*Ibid.*, 242.

¹²*Ibid.*

¹³*Ibid.*, 246.

¹⁴*Ibid.*, 248.

¹⁵William Owens, *Lifting the Fog of War* (New York: Farrar, Straus, and Giroux, 2000), 120.

¹⁶*Ibid.*, 133.

¹⁷Ibid.

¹⁸Ibid., 134.

¹⁹Ibid., 122.

²⁰Ibid., 140.

²¹Ibid., 139.

²²Ibid., 143.

²³Ibid., 146.

²⁴Ibid., 147.

²⁵James Oberg, *Space Power Theory* (Washington D.C.: Government Printing Office, 1999), 148.

²⁶Ibid., 151.

²⁷Ibid., 149.

²⁸Clayton Chun, "Shooting Down a 'Star': Program 437, the U.S. Nuclear ASAT System and Present-Day Copycat Killers" (Maxwell AFB: Air University Press, 2000), 33.

²⁹Ibid., 36.

³⁰Ibid., 22.

³¹Ibid., 19.

³²David Lupton, "On Space Warfare: A Space Power Doctrine" (Maxwell AFB: Air University Press, 1988), 35.

³³Ibid.

³⁴Ibid., 38.

³⁵Ibid., 93.

³⁶Ibid., 36.

³⁷Ibid., 39.

³⁸Ibid., 37.

³⁹Ibid., 125.

⁴⁰Alvin Toffler and Heidi Toffler, *War and Anti-War: Survival at the Dawn of the 21st Century* (Boston: Little, Brown and Company, 1993), 99.

⁴¹Ibid.

⁴²Ibid., 103.

⁴³Chang Mengxiong, "Weapons of the 21st Century," in *Chinese Views of Future Warfare*, ed. Michael Pillsbury (Washington, D.C.: National Defense University Press, 1998), 252.

⁴⁴Zheng Shenxia and Zhang Changzhi, "The Military Revolution in Air Power," in *Chinese Views of Future Warfare*, ed. Michael Pillsbury (Washington, D.C.: National Defense University Press, 1998), 302.

⁴⁵Chen Huan, "The Third Military Revolution," in *Chinese Views of Future Warfare*, ed. Michael Pillsbury (Washington, D.C.: National Defense University Press, 1998), 394.

⁴⁶Ibid.

CHAPTER 3

RESEARCH METHODOLOGY

Introduction

How will the space medium evolve over the next twenty years? Although the future is impossible to predict with certainty, one can state with confidence that current trends, events, and developments are shaping the future operational environment of space. It follows that the research methodology used in this thesis must provide a process for identifying trends, events, and developments having the potential to affect any nation's ability to operate freely in space. However, there is no guarantee that something thought to be significant in a current context will continue to be significant in a future one. The research methodology should also consider the influence of the future geopolitical environment. Finally, the research methodology must present a means of objectively evaluating the effect those key trends, events, and developments will have on the viability of space superiority as a strategic concept through the 2020 time frame.

Since it is unrealistic to expect any research methodology to look ahead twenty years with absolute accuracy, a more reasonable approach envisions and constructs plausible, alternative futures that can be used to explore the critical space decisions facing DoD. Scenario-based methodologies have been used to probe the future in this manner for nearly fifty years. Therefore, scenario learning was selected as the approach best able to satisfy the needs of this thesis. The real attraction of scenario learning is that it affords decision makers an opportunity to consider the future from different--perhaps unconventional--perspectives. The objective is not an accurate picture of tomorrow, but better decisions about the future.¹

Scenario Learning

The research methodology developed for this thesis is based on the principles of scenario learning outlined in *Learning From the Future*, edited by Liam Fahey and Robert M. Randall. Scenario learning, according to Fahey and Randall, involves two elements: constructing or developing scenarios, and integrating the content of scenarios into decision making.² Both elements are central to scenario learning; neither one alone is sufficient for successful scenario use. Accordingly, the research methodology is built around these two elements. As an additional point of introduction to scenario learning, it should be noted that the approach typically requires multiple (i.e., three or four) scenarios in order to define the full range of opportunities and threats facing an organization. In the case of this research effort, however, only one future scenario is fully developed. Although the research methodology is capable of developing additional scenarios, one scenario is adequate to demonstrate its utility in effectively addressing the question at hand.

There are many valid methods that can be used to construct scenarios and perform scenario learning. The approach used here is referred to as “future forward”; that is, it projects plausible futures based on an analysis of existing forces and their likely evolution.³ Developing scenarios in this manner presents a fundamental challenge: creating scenarios that deal with the issues that are most critical to the organization. In other words, not every current trend, event, and development will have a significant impact on the viability of space superiority as a strategic concept in 2020. The scenario development process must identify those that do and use them as a basis for constructing scenarios.

Scenario Development Process

The primary objective of the scenario development process is to construct scenarios that are focused on the needs of some decision, strategy, or plan.⁴ Proponents of scenario learning contend that by aiming scenarios toward making one or two specific decisions, it is possible to prevent the process from straying off into overly broad generalizations about the future. The scenario development process used in this research methodology is illustrated in figure 1. Here, the process is divided into three phases--identification of environmental forces, determination of driving forces, and extrapolation to 2020 scenarios. A detailed discussion covering each phase of the scenario development process follows.

Phase 1: Identification of Environmental Forces

The first phase of the scenario development process, shown in figure 2, aims to identify the relevant environmental forces--current events, trends, and developments--that form the basis of the scenarios. This phase begins with the selection of a decision focus. As the name implies, the decision focus is that key strategic decision upon which the scenario is focused. Virtually any decision or area of strategic concern in which external factors are complex, changing, and uncertain provides a suitable focus for the scenario process.⁵ Here, the decision focus is the primary question: Is space superiority a viable strategic concept through the *Joint Vision (JV) 2020* time frame?

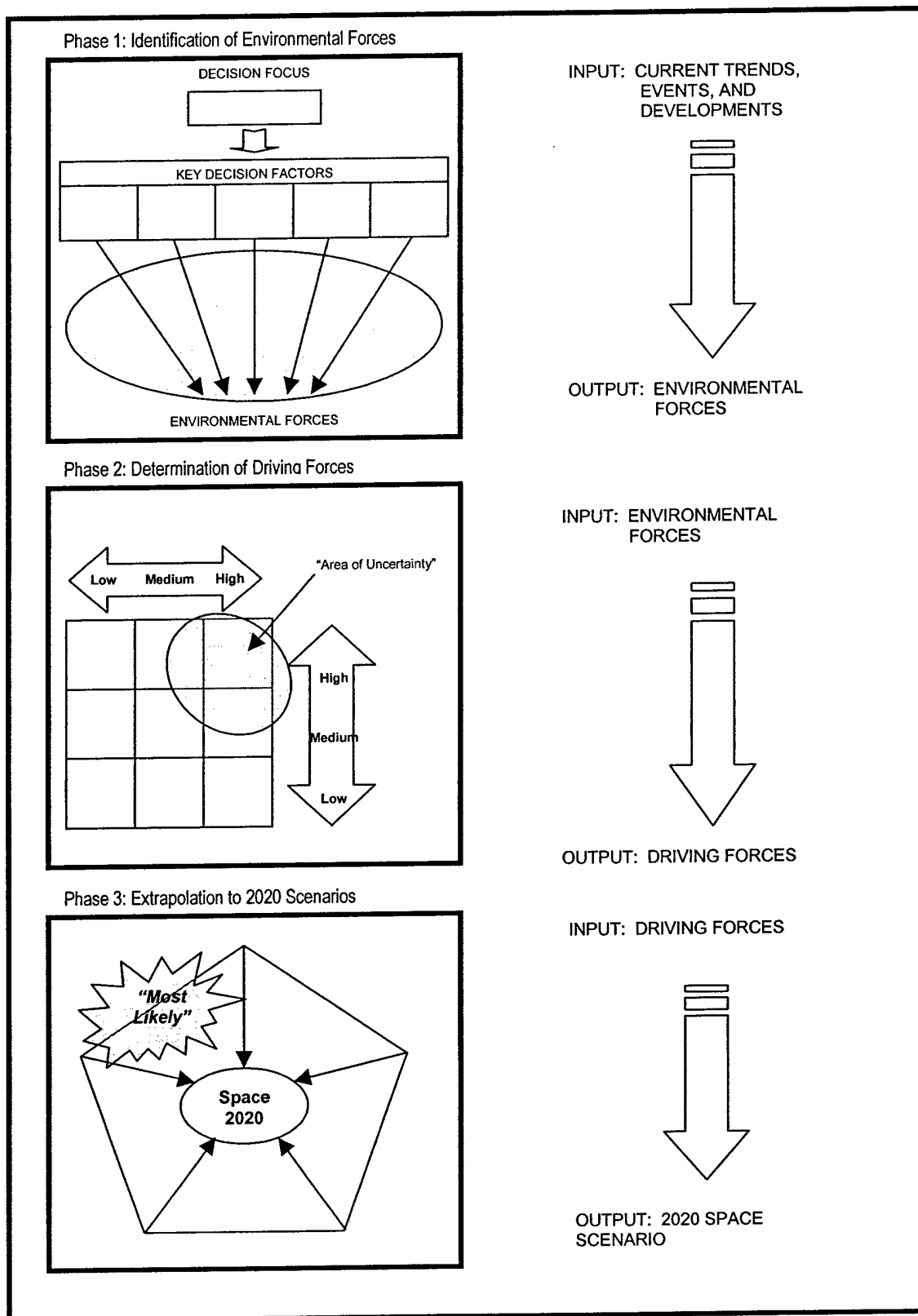


Figure 1. Scenario Development Process

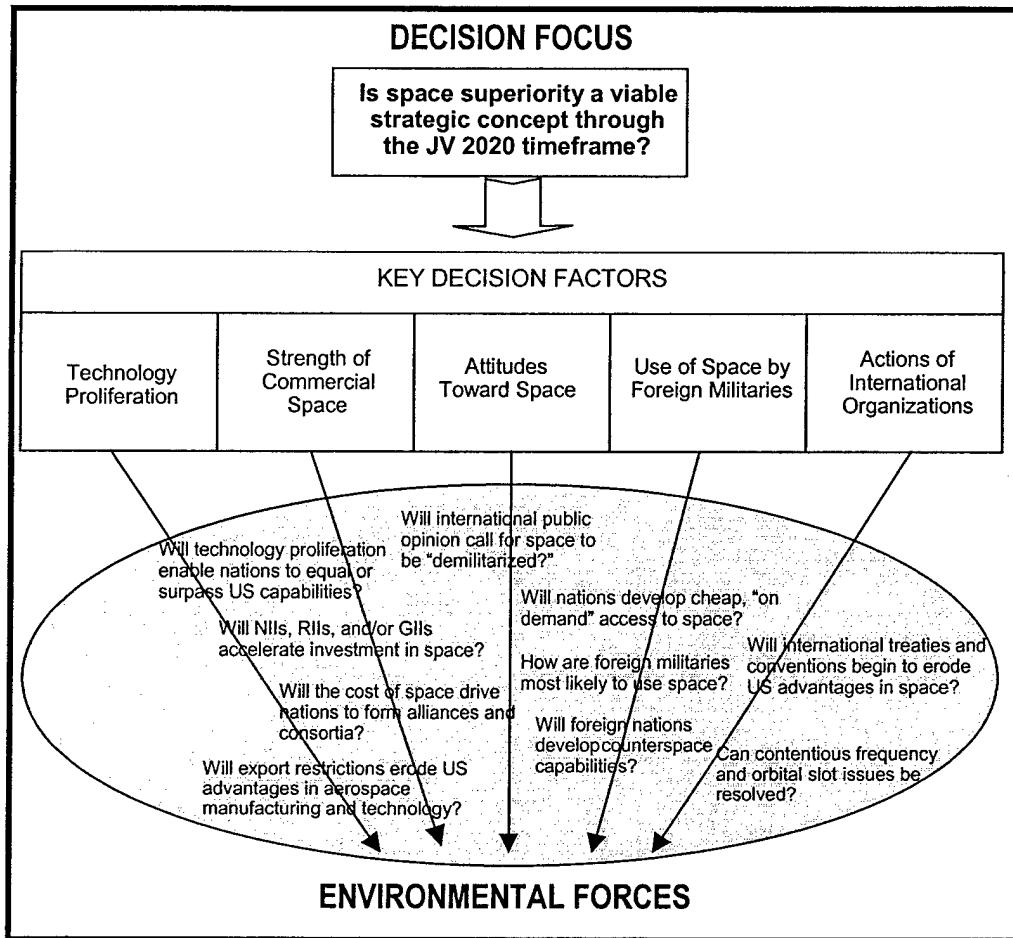


Figure 2. Identification of Environmental Forces

After selecting the decision focus, the next step is to determine what crucial particulars one would like to know about the future in order to make the decision. These are referred to as "key decision factors" in the lexicon of scenario learning. The choice of key decision factors is important--a well-thought-out set of key decision factors will provide the most insight as to forces driving the future environment. An important point to note about key decision factors is that they all relate to external, largely uncontrollable, conditions.⁶ External conditions are usually beyond the capability of any nation or group

of nations to unilaterally control. It is possible, however, to exert influence over external conditions.

This research methodology correlates key decision factors to the instruments of power--economic, informational, military, and political. Instruments of power are those means available to a nation through which it is able to exercise influence within a given region. If nations use the instruments of power to influence external conditions--key decision factors are related to external conditions--it follows that key decision factors are de facto objects of the instruments of power. Table 5 lists the five key decision factors and correlates each to an instrument of power. Strategists are very familiar with these instruments and routinely use them to assess an opponent's relative power within a geographic area of responsibility (AOR). Since space continues to mature as an AOR in its own right,⁷ it is logical to think in terms of the instruments of power when choosing key decision factors.

Table 5. Correlation of Key Decision Factors to Instruments of Power	
<i>INSTRUMENTS OF POWER</i>	<i>KEY DECISION FACTORS</i>
Economic	<ul style="list-style-type: none"> • Proliferation of Technology • Strength of Commercial Space • Attitudes Toward Space • Use of Space by Foreign Militaries • Actions of International Organizations
Informational	
Military	
Political	

The final step in this phase of the scenario development process is to identify the environmental forces that will determine the future course and value of the key decision factors. The objective is to begin to construct a good conceptual model of the relevant environment, one that incorporates all of the critical trends and forces. The model also should outline the key cause-and-effect relationships between environmental forces. Referring back to figure 2, notice that the secondary and tertiary questions discussed in chapter 1 are aligned with key decision factors. If a current event, trend, or development is not directly related to one of these questions, it is not considered for use as an environmental force. This helps identify only those environmental forces that are relevant to the decision focus. Additionally, it illustrates the relationship between environmental forces and key decision factors.

The framework used to identify relevant environmental forces is shown in table 6. This table provides the organizational structure for chapter 4. Secondary and tertiary questions are broken down into relevant issues; these become the focus of the data collection effort. Current trends, events, and developments--environmental forces--produced by the data collection effort provide the input to the next phase of the process.

Phase 2: Determination of Driving Forces

The purpose of phase two of the scenario development process is to assess future prospects for the environmental forces identified in the previous phase. The intent is to quickly focus on the fewest, most important forces. It is essential to recognize that while a typical scenario development process may generate over 50 environmental forces, the number of driving forces will be significantly lower.⁸ A complex, detailed

Table 6. Framework for Identifying Environmental Forces	
<i>DECISION FACTORS</i>	<i>RELEVANT ISSUES</i> (Derived from Secondary & Tertiary Questions)
Attitudes Toward Space	<ul style="list-style-type: none"> • Militarization of Space--Missile Defense and Space Control <ul style="list-style-type: none"> ➤ Political, Media, and General Public • Peaceful Use of Space--Civil Manned and Unmanned Programs <ul style="list-style-type: none"> ➤ Political Commitment
Strength of Commercial Space	<ul style="list-style-type: none"> • Industry Dynamics <ul style="list-style-type: none"> ➤ Profitability, Human Resources, and Restructuring • Market Dynamics <ul style="list-style-type: none"> ➤ Remote Sensing, Communications, and Launch • Financing <ul style="list-style-type: none"> ➤ Internal and External Sources • Future Opportunities and Challenges <ul style="list-style-type: none"> ➤ National, Regional, and Global Information Infrastructures ➤ Uncertainties, Competing Technologies, and Dual-Use Systems
Technology Proliferation	<ul style="list-style-type: none"> • Basic Research and Emerging Technologies <ul style="list-style-type: none"> ➤ Guidance & Navigation, Computers, Structures, Communications, and Remote Sensing • Small Satellite Developments <ul style="list-style-type: none"> ➤ Satellites, Operations, Launch, and Research • Technology Transfer <ul style="list-style-type: none"> ➤ Government and Commercial • International Trade <ul style="list-style-type: none"> ➤ Sanctions & Controls, Trade Laws & Restrictions, and Trade Environment
Use of Space by Foreign Militaries	<ul style="list-style-type: none"> • Incorporation of Space in War-Fighting Doctrine and Force Structure <ul style="list-style-type: none"> ➤ Doctrine and Acquisition & Integration • Counterspace Capabilities <ul style="list-style-type: none"> ➤ Space Based and Ground Based • Cheap "On-Demand" Access to Space <ul style="list-style-type: none"> ➤ Conventional Propulsion Systems
Actions of International Organizations	<ul style="list-style-type: none"> • Allocating the RF Spectrum <ul style="list-style-type: none"> ➤ Spectrum Management • Assigning Orbital Slots <ul style="list-style-type: none"> ➤ Slot Management • Governing the Use of Space <ul style="list-style-type: none"> ➤ Existing Treaties, Space Law Initiatives, and Global Space Utilities

analysis is generally not required here. At a minimum, an assessment of environmental forces includes the following:⁹

1. Their apparent direction today--current trends and the reasons for them.
2. Their future prospects--how much, in what ways, and how fast these trends might change in the future.
3. Their relevance to the decision focus--direction and magnitude of their impact on the future course of key decision factors.

A systematic sorting process is required to determine driving forces. A recommended approach is the use of an impact/uncertainty matrix, similar to the one shown in figure 3. This approach recognizes that environmental forces are not all equally important or equally uncertain.¹⁰ Using a straight-forward, high-moderate-low scoring system, it is possible to position each one of the environmental forces on the matrix. Each environmental force is rated in terms of the following criteria:

1. The level of its impact on key decision factors.
2. The degree of uncertainty as to the direction, pace, or fact of its future course.

As a result of this sorting activity, it is possible to determine those “high-impact/high-uncertainty” forces that are potential shapers of future scenarios.¹¹ Refer to chapter 5 for a discussion of environmental forces and their corresponding positions on the impact/uncertainty matrix.

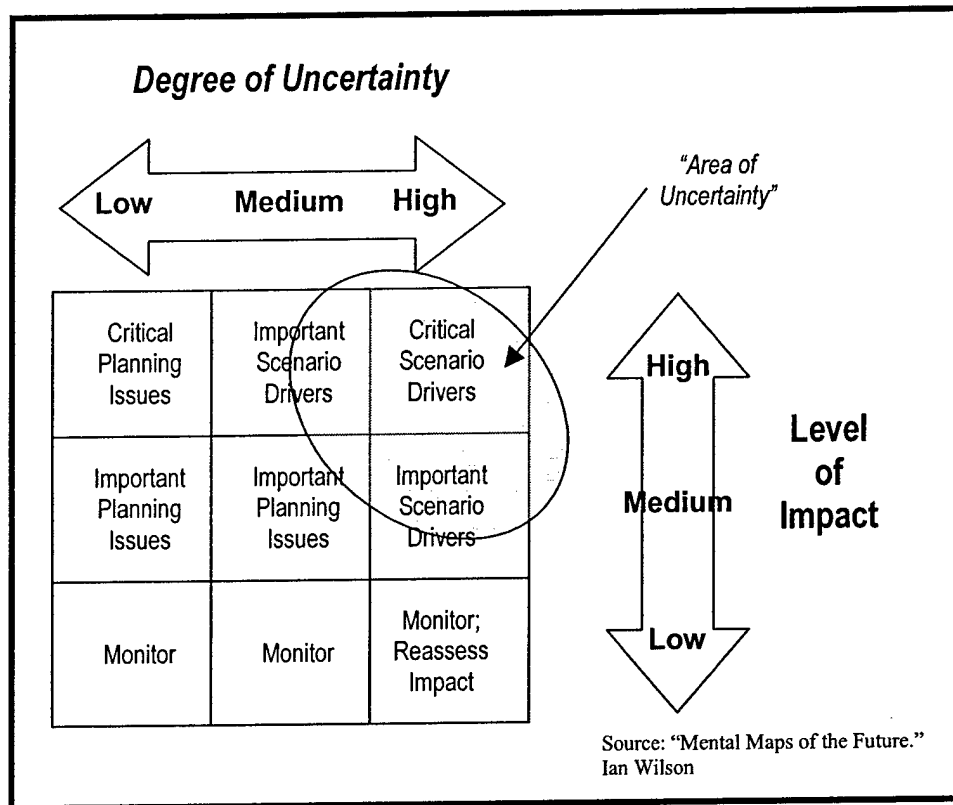


Figure 3. Impact/Uncertainty Matrix

Phase 3: Extrapolation to 2020 Scenarios

The last phase of scenario development involves the assembly of the future scenarios. Here, the logical rationale and structure for the scenarios is established. Intuition, insight, and creativity play the greatest role during this phase.¹² Consequently, this is the most likely place for bias to enter into the process. The literature review conducted in chapter 2 plays a key role in the effort to reduce this bias. Emphasis in the literature review is placed on gaining exposure to a wide variety of views discussing the future of space. This serves to temper any preconceptions held by the author and also provides a context in which any scenarios developed using this methodology can be placed.

The central challenge of scenario development is to develop a structure that produces a manageable number of scenarios in a logical manner.¹³ Three or four scenarios are typically required to contain the “area of uncertainty” highlighted in figure 3. However, based on the rationale previously stated in the chapter introduction, only one scenario is fully developed and evaluated in this thesis. This scenario is structured around a set of organizing principles called “scenario logics.” Scenario logics focus on critical uncertainties and present alternative theories of the way the world might work.¹⁴ In the case of this methodology, scenario logics are centered on the year 2020. The logics provide the rationale for taking current driving forces (identified in the previous phase) and extrapolating them to the year 2020. Before discussing the logics in greater detail, it is necessary to introduce several underlying tenets that have a direct bearing on how they are used.

The scenario logics used in this thesis are based on the contention that any future space environment must be a byproduct of the existing geopolitical environment. Stated another way, developments in the medium of space will occur within a larger strategic framework. Although this is an obvious point, it is usually not adequately addressed in projections of military space. Another key belief asserts that not all driving forces evolve at the same rate. Some drivers will become more important, others less so; interaction with the geopolitical environment is the determining factor.

The methodology draws on two previously published works to establish the scenario logics: *Strategic Horizons: The Military Implications of Alternative Futures*, by Dr. Steven Metz, U.S. Army War College, and *Global Trends 2015: A Dialogue About the Future With Nongovernment Experts*, prepared under the direction of the National

Intelligence Council. Each paper serves a distinct purpose in the scenario development process. *Strategic Horizons* projects alternative forms that the geopolitical environment might take in the future. This report is useful for the insight it provides as to how the world might work--at a macrolevel--in 2020. *Global Trends* addresses many of the critical uncertainties associated with the next fifteen-to-twenty years; it effectively establishes most of the scenario logics used by this methodology to extrapolate current driving forces to the 2020 time frame. The following discussion explains how the strengths of the aforementioned documents are used to construct the logics underlying the 2020 space scenario.

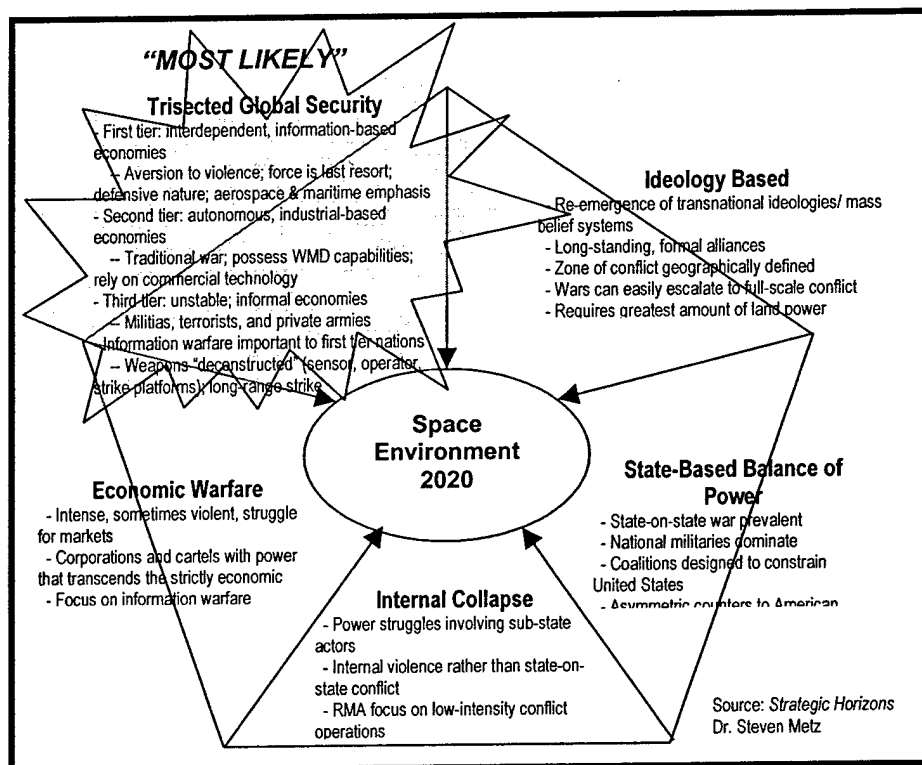


Figure 4. Alternative Futures--Security Environments

In *Strategic Horizons*, Metz hypothesizes that existing “currents of change” suggest a number of very different geopolitical environments are possible in the future. Figure 4 summarizes the five distinct systems developed by Metz: trisected global security, economic warfare, internal collapse, state-based balance of power, and ideology based.¹⁵ Although *Strategic Horizons* looks out to “2030 and beyond,” the speculative environments it provides are still relevant to this research--most are as applicable to 2020 as they are to 2030.

Of the five alternative futures postulated by *Strategic Horizons*, only one--trisected global security system--is used in this methodology. Metz believes this environment is “most likely” for the 2030 time frame.¹⁶ Since the trisected global security system most closely approximates the current geopolitical environment, it generally reflects a mainstream line of current strategic thinking. Note that each of the alternative futures developed by Metz requires a radically different U.S. military. Within the trisected global security system, the importance of space in future conflicts is unquestioned. It follows, therefore, that space superiority is highly desirable in this environment. In the case of several other alternative futures--for example, economic warfare and internal collapse--the role of space is probably not as vital. Although it is beyond the scope of this research, it would be interesting to use the remaining environments to drive scenario logics. The results may indicate how pervasive the requirement for space superiority is or is not over a range of prospective futures.

The trisected global security system establishes the underlying principles for how the geopolitical environment will function in 2020. Next, it is necessary to identify those major drivers and trends that will shape the world of 2020--within the limitations of a

trisected global security environment. *Global Trends 2015* is ideally suited for this task. Prepared by a diverse group of U.S. Government specialists and experts from outside the government (i.e., academia and the private sector), *Global Trends 2015* represents one of the most impartial, wide-ranging, views of the future available. The study identifies major drivers and trends that, taken together, create an integrated picture of the world in 2015. Even though the study's time frame does not extend beyond 2015, it is believed that any major driver or trend projected to be significant in 2015 will continue to exert influence through 2020.

An analysis of *Global Trends 2015* results in the identification of a number of trends relevant to the development of space. Each of the seven major drivers--demographics, natural resources and environment, science and technology, global economy and globalization, national and international governance, future conflict, and the role of the United States¹⁷--contribute at least one trend to the space 2020 scenario logics shown in table 7. Note that when the trends are viewed within the context of Metz' trisected global security system, there is considerable correlation. This indicates the assessments and conclusions from two independent sources have been successfully integrated into a coherent set of scenario logics.

Scenario assembly constitutes the last step in the scenario development process. Using the logics just developed, the driving forces from phase two are extrapolated to establish the 2020 space scenario. Having determined the scenario, its description must be further elaborated. In "Mental Maps of the Future," Wilson states scenario elaboration stresses three important features:

Table 7. Space 2020 Scenario Logics

The Nature of Conflict:

- The United States will remain the dominant military power
- Adversaries will pursue asymmetric capabilities against US forces and interests
- Adversaries will seek to attack US military capabilities through electronic warfare, psyops, and denial and deception--primary purpose to deny United States information superiority
- Probability that a missile armed with WMD would be used against US forces or interests will continue to grow
- International commercialization of space will give states and non-state adversaries access rivaling today's space powers
- Several countries will have counterspace capabilities

Demographics:

- More than 95 percent of the increase in world population will be in developing countries--nearly all in rapidly expanding urban areas
- By 2015, more than half of the world's population will be urban

National and International Governance:

- Non-state actors will play increasingly larger roles in both national and international affairs
- Governments will have less and less control over flows of information across their borders
- Globalization will increase the transparency of government decision-making

Science and Technology:

- IT revolution represents the most significant global transformation since the Industrial Revolution
- Prospect of universal wireless connectivity via hand-held devices; large numbers of low-cost, low-altitude satellites
- Export control regimes and sanctions will be less effective because of the diffusion of technology
- IT will make major inroads in rural as well as urban areas around the world

Role of the United States:

- Some states--adversaries and allies--will try at times to check what they see as American "hegemony"
- The United States will remain in the vanguard of the technological revolution

Global Economy and Globalization:

- Networked global economy will be driven by rapid and largely unrestricted flows of information

Natural Resources and Environment:

- International or multilateral arrangements will increasingly be called upon to deal with growing transnational problems--to include the competition for scarce resources

- Denotes correlation with tri-sectored global security system

Source: *Global Trends 2015*
National Intelligence Council

1. A Highly Descriptive Title--conveys the essence of what is happening in the scenario.

2. Compelling Story Lines--a narrative of how events unfold between now and 2020.

3. A Table of Comparative Descriptions--discusses what might happen to the most important forces in the scenario.

The fully developed space scenario is found in chapter 5. At this point, the emphasis of the discussion shifts to explaining how this scenario is integrated into the decision-making process and used to evaluate the viability of space superiority as a strategic concept in 2020.

Strategic Concept Viability

The strategy for space superiority presented in chapter 1 provides a plausible set of objectives, strategic concepts, and resources that can be assessed within the context of a future setting. Since the thesis focuses on determining the viability of space superiority as a strategic concept, the key analytical task for this part of the research methodology shifts to evaluating the strategic concept in a 2020 environment. The 2020 space scenario provides an estimate of the strategic environment; criteria for feasibility, acceptability, and suitability (FAS)--applied within the bounds of this estimate--determine the viability of the strategic concept. If the strategic concept satisfies a majority of FAS criteria, it will be considered "viable." A viable strategic concept means it may be possible for the United States to maintain space superiority through the year 2020--resources permitting.

Figure 5 graphically depicts how the strategic concept will be assessed and evaluated. The process has two analytical steps and involves more art than science. This will become apparent in the following discussion.

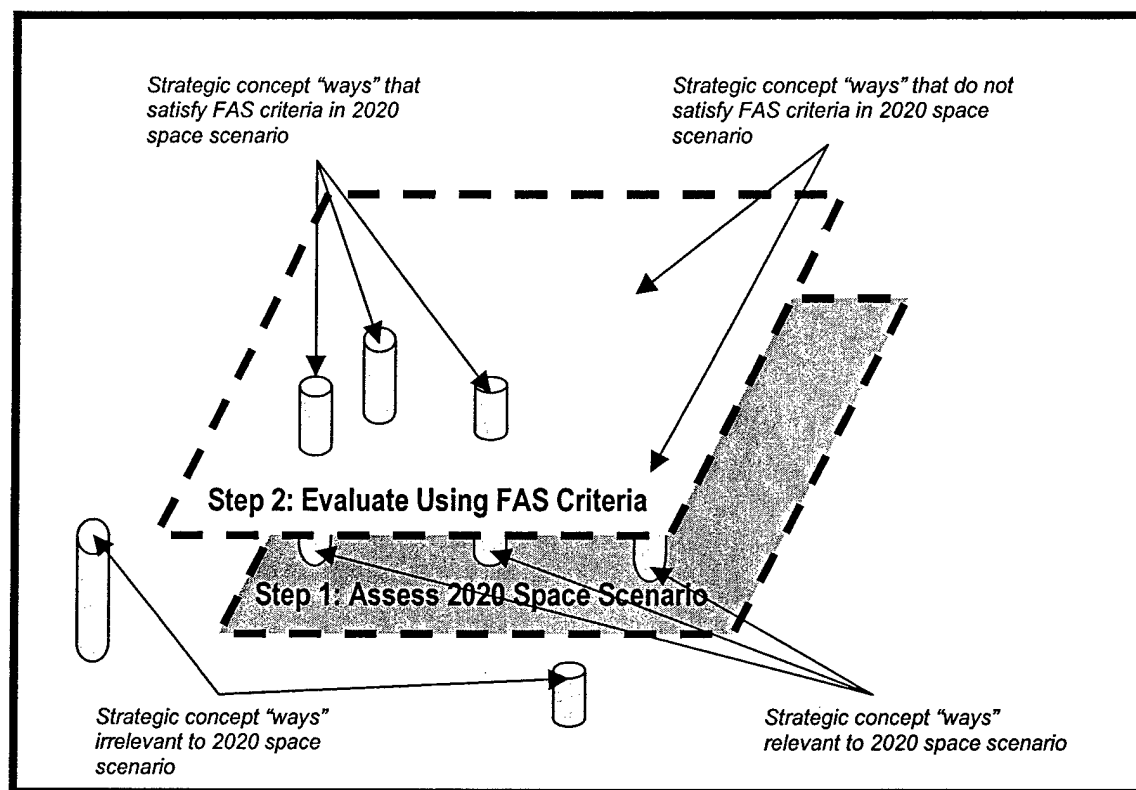


Figure 5. Strategic Concept Evaluation

Assessing the Strategic Concept in 2020

Before the strategic concept can be evaluated, it must be assessed within the 2020 space scenario. Recall the notional strategy was derived from unclassified DoD publications and the 2020 scenario was developed using a scenario learning process. Since both the strategy and the scenario were arrived at via independent methods, it is necessary to establish a linkage between the two. Assessing "ways" (i.e., methods of

applying military force) that make up the strategic concept against logics that outline the space scenario establishes the required nexus. This places strategic concept “ways” into one of two categories--those that are relevant to the scenario and those that are not. Relevant “ways” will be evaluated using FAS criteria; irrelevant “ways” will be removed from the strategic concept and not be evaluated. This is represented in figure 5.

Evaluating the Strategic Concept Using FAS Criteria

Military strategists employ FAS criteria for evaluating strategy to ensure national security is not in jeopardy. In fact, note that FAS criteria have been included in Appendix B, JCS Pub 3.0, as an accepted means of “testing” a strategic course of action. Here, the research methodology uses a tailored set of FAS criteria to test the viability of space superiority as a strategic concept. It is important to recognize, however, that FAS criteria evaluate more than just the strategic concept. They also examine whether the military objectives are suitable and the means required are acceptable.¹⁸ Therefore, it follows that the viability of the strategic concept is a function of its ability to satisfy military objectives in a cost effective manner.

Before the FAS evaluation matrix used in this methodology is introduced, it is useful to have a basic understanding of the FAS criteria. In an article discussing military strategy Lieutenant Colonel Ted Davis, USA (retired), defines each FAS criterion¹⁹ as follows.

Feasibility

Feasibility is defined as an assessment of the strategic concept given the resources available. Based upon comparative resources, feasibility considers friendly capability

versus threat capability given the nature of the environment. A test for feasibility is primarily a military evaluation requiring both intuitive and experiential skills on the part of the evaluator.

Acceptability

Acceptability examines the issue of cost: "Are the consequences of cost justified by the importance of the effect desired?" Acceptability considers both tangible (e.g., dollars and personnel) and intangible costs (e.g., prestige and public support). For a strategic concept to be considered "acceptable," it must also be consistent with the law of war and politically supportable. As with the previous case, determining acceptability involves a combination of art and science.

Suitability

Suitability confirms the linkage between military and national security objectives. A military objective is considered "suitable" if its attainment will accomplish the desired political effect. The suitability test requires mostly intuitive skills because it frequently involves translating intangible political objectives into tangible military objectives.

FAS Evaluation Matrix

Based on the definitions of feasibility, acceptability, and suitability discussed in the previous section, questions were developed to test the viability of the strategic concept. These questions form the basis of the evaluation matrix shown in table 8. Although the analysis found in chapter 5 evaluates the strategic concept using only a single scenario--the "most likely" environment based on Metz' trisected global security

Table 8. FAS Criteria--Example of a Multiple Scenario Evaluation Matrix			
Scenario	<i>"Most Likely"</i>	<i>"Most Dangerous"</i>	<i>"Most Unpredictable"</i>
FAS Criteria			
Feasibility			
<ul style="list-style-type: none"> In 2020, are sufficient resources to accomplish space superiority likely to be available? 	Y/N	Y/N	Y/N
<ul style="list-style-type: none"> Given the 2020 environment, is space superiority likely to be technically possible? 	Y/N	Y/N	Y/N
<ul style="list-style-type: none"> Given the 2020 environment, is space superiority likely to be operationally achievable? 	Y/N	Y/N	Y/N
Acceptability			
<ul style="list-style-type: none"> Given the environment, are there likely to be adverse consequences related to space superiority? 	Y/N	Y/N	Y/N
<ul style="list-style-type: none"> Will space superiority be consistent with international law? 	Y/N	Y/N	Y/N
<ul style="list-style-type: none"> Is it possible that the cost--in terms of the instruments of power--of space superiority will become too high? 	Y/N	Y/N	Y/N
Suitability			
<ul style="list-style-type: none"> Is the attainment of space superiority likely to be compatible with other .S. national security objectives? 	Y/N	Y/N	Y/N
<ul style="list-style-type: none"> Is the current concept of space superiority likely to change before the year 2020? 	Y/N	Y/N	Y/N

system--the approach is applicable to multiple scenarios as well. The purpose of presenting the evaluation matrix in this format is to highlight its usefulness in comparing results obtained under a variety of conditions. Subsequent research may wish to consider the primary question using these alternative scenarios.

Referring again to figure 5, the effect of the FAS criteria on the strategic concept's relevant "ways" is clearly shown. Ways protruding through the upper plane of the diagram indicate the FAS criteria have been satisfied. Essentially, the criteria serve as a filter, eliminating ways that are not feasible, acceptable, and/or suitable. Determination of viability now becomes a matter of ascertaining whether enough ways continue to exist after the strategic concept has been assessed and evaluated in the 2020 environment.

At this point, that element of strategy most commonly considered "art" enters into the methodology. A certain degree of intuitive judgment is inescapable when evaluating the ability of a strategy to secure national objectives. Lieutenant Colonel Davis reaffirms this point with the following observation:

The art of strategy is an intuitive translation based on the experience, education, and wisdom of senior military leaders.²⁰

In spite of the fact that the objective of this methodology has been to develop a process that emphasizes the "science" of strategy making, the final evaluation of viability encompasses both art and science. Any attempt to develop a wholly scientific process would be destined to fail. Results from this analysis are presented in chapter 6.

Conclusion

As space continues to develop as an AOR, the need to develop a coherent national space strategy will become increasingly apparent. The research methodology presented here is an attempt to address this requirement. The objective is to demonstrate the applicability of this methodology in evaluating a strategic concept before expanding it (at some point in the future) to take on the larger problem of supporting an overall space strategy making process. The methodology also strives to develop a "normalized" process based on analytical tools familiar to many strategists--scenario learning and FAS criteria evaluation. Space strategists should adopt these proven techniques from the more traditional applications of strategy making. In this manner, military space strategy can begin to emerge as a discipline in its own right.

¹Peter Schwartz, *The Art of the Long View* (New York: Doubleday, 1991), 9.

²Liam Fahey and Robert M. Randall, "What is Scenario Learning?" in *Learning From the Future* (New York: John Wiley & Sons, Inc., 1998), 5.

³*Ibid.*, 19.

⁴Ian Wilson, "Mental Maps of the Future: An Intuitive Logics Approach to Scenarios," in *Learning From the Future*, ed. Liam Fahey and Robert M. Randall (New York: John Wiley & Sons, Inc., 1998), 83.

⁵*Ibid.*, 84-85.

⁶*Ibid.*, 86.

⁷*Report of the Commission to Assess United States National Security Space Management and Organization: Executive Summary*, by Donald H. Rumsfeld, Chairman (Washington, D.C.: GPO, 2001), 55.

⁸Wilson, "Mental Maps." 88.

⁹*Ibid.*

¹⁰*Ibid.*

¹¹Ibid., 89.

¹²Ibid.

¹³Ibid., 90.

¹⁴Ibid.

¹⁵Steven Metz, *Strategic Horizons: The Military Implications of Alternative Futures* (Carlisle Barracks: US Army War College, Strategic Studies Institute, 1997), vi-vii.

¹⁶Ibid.

¹⁷*Global Trends 2015: A Dialogue About the Future With Nongovernment Experts*, by John Gannon, Chairman, National Intelligence Council (Washington, D.C.: GPO, 2000), 4.

¹⁸Ted Davis, "Evaluating National Security Strategy and National Military Strategy," in *Fundamentals of Operational Warfighting*, vol. 1 (Fort Leavenworth: US Army Command & General Staff College, Department of Joint and Multinational Operations, 2000), L1-E-1.

¹⁹Ibid., L1-E-1 and L1-E-2.

²⁰Ibid., L1-E-2.

CHAPTER 4

CURRENT TRENDS, EVENTS, AND DEVELOPMENTS

Introduction

The complexity of the space environment is perhaps no better illustrated than by the amount of data collected in this chapter. Adherence to the research methodology outlined in chapter 3 led to the identification of over 100 trends, events, and developments--that is, "environmental forces"--that serve to define the current environment and shape the future one. While some may argue for the insertion or deletion of particular forces, the aggregate group presented here captures the essence of what is currently taking place with respect to space.

Identification of Environmental Forces

The overarching framework for this chapter is based upon the key decision factors listed in table 5, chapter 3. Recall that each key decision factor directly correlates to an instrument of national power--that is, economic, informational, military, and political. Ultimately, this ensures that each element of "space power" discussed in chapter 2 is considered for inclusion in the future scenario. Additional structure is lent to the framework by defining the key decision factors in terms of relevant issues (see table 6, chapter 3). These issues effectively guided the overall data collection effort.

Prior to constructing the scenario, it is necessary to reduce the number of environmental forces down to more manageable number of "critical scenario drivers." Scoring environmental forces in terms of uncertainty and impact facilitates that process. Additionally, an overall assessment of apparent direction today, future prospects, and relevance to the decision focus was made for each grouping of forces.

Attitudes Toward Space

In the future, what is overtly permissible in space will be determined by the prevailing attitudes of the political leadership, the media, and the general public. As the Cold War space paradigm gradually fades into obscurity, one must wonder how the public will respond now that they have a say in establishing the new order. How deep and how broad is the support among the American public for an increased military presence in space, be it missile defense or counterspace? Conversely, and in recognition of the fact that there is an international dimension to consider as well, how does the rest of the world feel about future U.S. plans for space?

“Militarization” of Space--Missile Defense and Space Control

Apparent Direction Today: Faced with a position of weakness in space, vis-à-vis the United States, the Russian Federation and the People’s Republic of China have no choice but to collectively oppose what they term the “militarization” of space. The focus of Russian and Chinese information operations (IO) campaigns is the American public--specifically, its attitude toward the use of space. A two-pronged approach attempts to: (1) isolate the United States diplomatically in international bodies, such as the United Nations, and (2) alter U.S. public opinion by playing up fears of a new “arms race” in space.

Future Prospects: There likely exists significant opposition--both within this country and abroad--to an increased military presence in space. If the United States continues with announced plans to conduct an on-orbit demonstration of a space-based laser prototype in the 2012-2013 time frame, expect the IO campaigns to continue and to become much more aggressive in nature. In the absence of a major trigger event, for

example, a ballistic missile attack on the United States or an ASAT attack on a U.S. satellite, American support for an increased military presence in space is likely to remain “soft” and vulnerable to such approaches. Few Americans give space much more thought than whether or not the reception is clear on their satellite TV system; even fewer have thought through the ramifications of space superiority.

Relevance to Decision Focus: Public attitudes toward space are extremely relevant to the strategic concept of space superiority. In the absence of a major trigger event, the process for maintaining space superiority in the future will have to be a gradual one.

Political

Position on Militarization--Russian Leadership (1). Uncertainty: High; Impact: High. In September 1997, Russian President Boris Yeltsin sent a personal letter¹ to President Clinton expressing his concern over the lasing of an Air Force satellite by the Army's Mid-Infrared Advanced Chemical Laser (MIRACL). The MIRACL test was intended to simulate both an inadvertent lasing and a hostile attack on a U.S. satellite. Opponents of the test--including some Congressional leaders--saw it as a first step toward developing an antisatellite (ASAT) capability. The following quotes extracted from the Yeltsin letter illustrate specific Russian concerns over the ASAT issue:

We are alarmed at the U.S. military's intention to develop a whole gamut of anti-satellite weapons systems.

At one time we possessed an antisatellite capability. We renounced it as soon as we realized the futility [of] a first-strike notion.

The immediate goal is to agree on the ban on any systems destroying strategic warning satellites. Then the problem of how to deal with possible destabilization in low orbits should be tackled.

Position on Militarization--Chinese Leadership (2). Uncertainty: High; Impact: High. Chinese leadership has been critical of U.S. plans to increase its military presence in space. The Chinese have used the United Nations Conference on Disarmament (CD) as a forum to advance their agenda, which calls for a negotiated ban on the “weaponization of outer space.” In particular, the Chinese are opposed to the development of space-based theater and national missile defense (TMD and NMD) systems. China’s ambassador to the CD, Hu Xiaodi, has served as a primary spokesman for the Chinese position, arguing:

Even a layman can see that the above mentioned program will inevitably introduce relevant weapons or weapons systems into outer space, which will turn outer space into a new weapon base and a battlefield.²

Media

Position on Militarization--Indian Media (3). Uncertainty: Moderate; Impact: Moderate. Media reaction in other countries has often been critical of U.S. plans to increase the military presence in space. One opinion, taken from the Indian daily *The Hindu*, expressed dismay over the “militarization” of space.³

Moves of militarization of space can only be reflective of a mad death wish given the possibilities for annihilation they could unleash, from which the end of the Cold War should have saved the human race.

Position on Militarization--Chinese Media (4). Uncertainty: Low; Impact: Moderate. The State-controlled media in the People’s Republic of China has consistently denounced U.S. intentions to control space. *People’s Daily*, the official newspaper of the Chinese Communist Party, condemned a recent (January 2001) Air Force-sponsored space war game as “traditional Cold War thinking.” *Jeifangjun Bao*, the newspaper of

the People's Liberation Army, has argued that China needs to increase its military presence in space because NATO forces are becoming "increasingly space militarized."⁴

General Public

U.S. Opinion on Militarization (5). Uncertainty: High; Impact: High. Limited polling data finds the American public generally supportive of increasing the military presence in space. An unscientific poll conducted on 8 Oct 2000 by the Cable News Network (CNN) website asked the following question: "Is there too much military technology in space?" 73 percent of the respondents felt there was not too much military technology in space and that it was vital for stability around the world; 27 percent indicated an increased military presence posed a threat to peace and security.⁵ Other polls of a more scientific nature have found fairly broad levels of support for the development and construction of a national missile defense (NMD) system. A Gallup poll taken in July of 2000 found slightly more than half of the American public supported the construction of a missile defense system.⁶ Results from a poll conducted by McLaughlin & Associates showed seven of ten Americans strongly supported the development of a NMD system.⁷ Although neither of these polls directly asked the participants if they supported the militarization of space per se, the results are significant given the widespread association of NMD with space-based weapons.

In the United States, support for plans to increase the military's presence in space is not universal. One view holds that the American people should demand a public debate on Bush administration plans for the militarization of space. Karl Grossman, author of *Weapons in Space*, contends that the only part of the Administration's plan getting scrutiny, now--as in the 1960s--is missile defense.⁸ Grossman believes U.S.

Space Command wants to use its satellites and computer network not only to guide weapons, but to destroy enemy satellites as well.

International Opinion on Militarization (6). Uncertainty: High; Impact: High.

Could the weight of international opinion be used to temper U.S. technological superiority? According to a National Defense University (NDU) paper entitled “Dragons in Orbit,” this is possible--especially in situations where the United States itself is not directly threatened.⁹

International Movement to Prevent Militarization (7). Uncertainty: Low; Impact:

Low. There exists a small, loosely connected, international movement that opposes the militarization of space. This “movement” has used a variety of methods in an attempt to have all weapons banned from space. On 7 October 2000, an alliance of organizations--including the Green Party and Greenpeace--conducted protests in 60 cities spread throughout 16 countries.¹⁰ The rallies were held as part of an international day to speak out against military space technology. Organizers criticized NMD and called for a strict adherence to the Anti-Ballistic Missile (ABM) Treaty and the Outer Space Treaty.

In the United States, groups, such as the “Global Network Against Weapons and Nuclear Power in Space” and “Veterans for Peace,” have tried to exert pressure on the political process by calling for the rejection of certain individuals nominated for key positions in the Department of Defense (DoD). The appointment of Donald Rumsfeld as Secretary of Defense was a particularly controversial one among these groups--given his positions on missile defense and space control.¹¹ These groups have also encouraged citizenry to become active in changing the political process as a means of influencing the

debate over the militarization of space. Leaders have urged others to inspire the public to challenge the Administration's policies at the ballot box, and if necessary, in the streets.¹²

European peace groups have been no less vocal in their calls for a prohibition on military projects in space. One group has demanded adherence to the ABM Treaty and wants it to be broadened in scope to include a European dimension. This group also endorses more radical concepts, calling for the U.N. to make clear statements against any military use of space and to strengthen its position with regard to dual-use.¹³

Peaceful Use of Space--Civil Manned and Unmanned Programs

Apparent Direction Today: The effect of civil space programs, particularly manned efforts, on a nation's psyche should not be overlooked. Consider the feelings of intense pride generated by the Apollo program during the late-1960s and the space shuttle program in the early-1980s as proof of the unifying power of space. Now, compare those times with what is happening in China. William Gibson, the highly acclaimed science fiction writer, likens the prevailing mood in China to that which existed in United States during the early days of the space race: "China has invested enormous emotional belief in the goodness of space travel. Their enthusiasm is the highest in the world--where we were in the 1950s."¹⁴

Future Prospects: History has shown that manned space programs are a tremendous source of national pride and also can serve as a catalyst for a nation's overall space effort. As the Chinese achieve success in the manned program, expect to see a corresponding boost in their unmanned efforts as well. Additionally, India may find itself in a similar position at some point in the 2010-2020 time frame.

Relevance to Decision Focus: To this date, the only nation to rival the United States in space has also been the only other nation to place a man into orbit using its own man-rated systems. The ability of any nation to launch a human into orbit demonstrates a significant economic and political investment in space and may portend the emergence of a peer or near-peer competitor. One can argue that only a peer or near-peer can challenge the ability of the United States to maintain space superiority.

Political Commitment

Civil Manned Program--China (8). Uncertainty: Low; Impact: Moderate.

China's manned space program was the subject of much speculation prior to its first successful test flight (an unmanned event) on 21 November 1999. Whether it was for fear of an embarrassing failure, or just another example of China's penchant for secrecy, very little information was initially released regarding this program. Over the course of the past year, however, the Chinese have become much more forthcoming about this program. In a speech made during World Space Week, 4 to 10 October 2000, Luan Enjie, director of the State Aerospace Bureau, confirmed China's near-term goal of placing a man in orbit.¹⁵ Many analysts believe China will send "yuhangyuans" (astronauts) into space by the end of 2002, thus joining the United States and Russia as the only nations with domestic manned space programs.

Civil Unmanned Program--China (9). Uncertainty: Low; Impact: High. China is also pursuing an unmanned space program. China has publicized its intentions to explore the moon--initially using robots as an advance team for astronauts--and to partake in international missions to Mars.¹⁶ Chinese writings suggest space will be continue to be a national objective, given the political prestige and economic benefits attendant from a

robust national space program.¹⁷ Recent public statements by Chinese government officials support this assertion. Two quotes, again from Luan Enjie, serve to highlight this attitude:

Presently, the development of space technologies and the level of their applications become an indicator of a nation's united power and development of its civilization.¹⁸

If China since the 1960s had not had the atomic bomb and hydrogen bomb, nor launched its own satellites, China would not be regarded as an influential, powerful country.¹⁹

Civil Unmanned Program--Russia (10). Uncertainty: Moderate; Impact: High.

Speaking to a session of Russia's Security Council, President Vladimir Putin made the following statement:

Space isn't just a matter of national prestige, although that is important too, space means the latest technology that is the foundation of the competitiveness of the economy and the security of our nation.²⁰

President Putin recognizes that Russia must reverse the decline of its space industry. By all accounts, the resources of the once-proud Russian civil space program are virtually exhausted. Launch and ground control infrastructure is on the verge of failure and research has stopped.

Strength of Commercial Space

The bloom is surely off the rose in commercial space. And I think it's going to recover, but it's not going to be the way we thought it was going to be three or four years ago, with the skies darkened by commercial satellites.²¹

General Thomas Moorman, USAF (retired)

In the mid-1990s, many knowledgeable people in the space business truly believed an additional 1,500 satellites would be launched into orbit by the end of 2010.

At that time, there was plenty of reason for optimism. Constellations consisting of tens, even hundreds, of satellites were being constructed for launch. New “start-up” companies were at work designing innovative concepts for reusable launch vehicles. Service providers were lining up funding for their next generation of broadband satellites. Stock prices were up. The space industry was booming in all sectors.

Scarcely five years later, the situation has changed dramatically. What happened? First, several multi-billion dollar constellations were launched and declared operational-- Motorola’s Iridium and Loral’s Globalstar--only to find the actual market for their services was no where near original projections. Second, there were systemic weaknesses within the industry that were glossed over by optimistic estimates of demand for space-based information services. Now, when one looks at commercial space, one sees only weakness and uncertainty. This section reviews those trends, events, and developments occurring within the previous three years that lead one to this assessment.

Industry Dynamics

Apparent Direction Today: In 1998, commercial spending on space systems surpassed government spending for the first time.²² Data compiled by the Satellite Industry Association (SIA) indicates that commercial space is already a significant industry in its own right. Based on data collected from over 700 companies, the SIA estimates the industry generated over \$61.3 billion economic activity for the U.S. economy in 1999.²³ Table 9 provides a breakout of economic activity, earnings, and jobs. Note that in the United States, satellite/ground equipment manufacturing is the largest sector.

Table 9. Economic Impact of Commercial Space Industry			
Sector	Economic Activity	Earnings	Jobs
Launch Vehicle Manufacturing	\$3.5 billion	\$1.07 billion	28,617
Satellite/Ground Equipment Manufacturing	\$30.9 billion	\$8.8 billion	270,448
Satellite Services	\$25.8 billion	\$6.1 billion	186,954
Remote Sensing	\$0.2358 billion	\$0.0852 billion	2,820
Distribution Industries	\$0.8739 billion	\$0.2657 billion	8,506
Source: Satellite Industry Association			

Future Prospects: Conventional wisdom holds that commercial space will become increasingly predominant over military space through the year 2005 and beyond. Mr. Ken Gordon, executive director of the Center for Space Policy and Strategy at The Aerospace Corporation, believes that the space industry, after years of receiving "special treatment" as something of national interest, now must stand on its own merit. According to Gordon, "We need to be just another industry."²⁴ However, worldwide data collected for the year 2000 indicates that satellite services are the largest and fastest growing sector of the industry. According to SIA's fourth annual "Global Satellite Industry Indicators Survey," satellite services generated a total of \$39.5 billion in revenue in 2000, a 29 percent increase over 1999.²⁵ Perhaps the most significant trend in the commercial space industry today is the increasing dominance of marketing services over building satellites.

SIA data notwithstanding, current trends, events, and developments call into question the ability of the U.S. industrial base to sustain more than one major satellite manufacturer. Given the consolidation occurring within the European space industry, it would appear the once dominant global position of U.S. satellite manufacturers is nearing an end. Europe, with its own development model, and continuing efforts, has become a space power potentially capable of ensuring both nondependence in many fields of its

political decisions and substantial economic benefits in the applications of space technology.²⁶

Relevance to Decision Focus: The presence of a competitive, robust, domestic space industry is vital to the ability of the United States to maintain space superiority now and in the future. The DoD relies upon U.S. manufacturers to develop space technology that is unsurpassed by any nation on Earth. Any reduction in commercial manufacturing expertise and capacity adversely affects U.S. strength in military space.

Profitability

Refocusing the Industry--Manufacturing to Services (11). Uncertainty: High; Impact: High. The commercial space industry no longer sees satellite manufacturing as its primary source of revenue. After a decade of consolidation, only a handful of satellite manufacturers remain active and capable of delivering complete "turnkey" systems.²⁷ Companies previously known for their expertise in manufacturing are now focusing on developing and providing services to users. Consider the following three major U.S. players involved in the space industry--Hughes, Lockheed-Martin, and Loral. Hughes is no longer in the business of building satellites and space hardware, having sold its manufacturing unit to Boeing. Hughes now focuses exclusively on providing satellite services such as DTH television and data networking to consumers and businesses. In explaining their decision, Hughes officials said that services would grow faster and have greater impact on profits than manufacturing hardware.²⁸ Likewise, Lockheed-Martin is also exploring options for its commercial space business. According to Mr. Robert Stevens, Lockheed-Martin's president and chief operating officer, "Lockheed's growth opportunities are not going to be in space." Finally, Loral has seen the price of its stock

fall by over 90 percent as the company has been hurt by the failure of Globalstar to attract enough users to break even. Loral also has been the subject of much speculation as to whether or not it will seek to merge its manufacturing assets with a larger corporation. Meanwhile, Loral's satellite-services business posts record gains.

The primary reason why satellite manufacturers are looking to remake themselves as a service business is declining profit margins. The *Space Industrial Base Study* found that "an unhealthy financial picture characterized by overcapacity and decreasing margins, inadequate innovation investment, and a decline in human resources could undermine the long-term sustainability of the domestic (space) manufacturing base."²⁹ Consider that in 1980, the return on sales before investment was about 8.5 percent.³⁰ By the end of the 1987, return on sales had fallen to between below 7.5 percent; more recent numbers are down to 7.0 percent.³¹ According to General Moorman, now an analyst at Booz, Allen, and Hamilton, "We don't think it's coming back up [to previous levels]." Conversely, if one looks at the services business, return on sales range from 15-to-25 percent.³²

In order to increase overall profitability, satellite industry officials are trying to remake themselves as providers of complete communications solutions. Regional and global satellite firms long content to sell transponder capacity to other companies are now hastily forming in-house units to tailor their services to customers who in the past were uninterested in satellite services.³³ Most of the mass-market consumer satellite services vendors also have come to realize that they cannot succeed on national markets alone. The need to achieve economies of scale, scope, and technology, as well as global financial markets, will force these projects to leverage global markets.³⁴

Competition in the Global Marketplace (12). Uncertainty: Low; Impact: High.

Both the European and Chinese space industries are attempting to position themselves to compete with U.S. industry in the near term. The Europeans are committed to “promoting and supporting the global competitiveness and non-dependence of the European space industry at prime and supplier level through a long-term perspective.”³⁵ Their overall objective is to ensure nondependence and self-sufficiency in strategic key technologies, in addition to space access and applications. Li Zuhong, president of the Chinese Academy of Space Technology, stated that China will prepare to enter world market by mass-producing satellites “in a fast and economical manner.”³⁶

Human Resources

Competition for Scientific & Engineering Talent (13). Uncertainty: Moderate;

Impact: Moderate. Foreign nationals constitute approximately 40 percent of the students enrolled in engineering and science programs at American universities. Contrary to 20 or 30 years ago, when these people were staying in the United States to work, many today are choosing to return home to work in expanding local aerospace industries.³⁷

Demographics--Retention and Retirement (14). Uncertainty: Low; Impact: High.

U.S. defense contractors face a “graying” workforce that is quickly nearing retirement age. In 1999, 42 percent of the U.S. aerospace workforce was between the ages of 45 and 64.³⁸ Additionally, the aerospace industry is attracting fewer recruits out of a decreasing pool of engineering graduates. In the 1995-96 school year, 61,185 bachelors degrees were awarded in engineering from American universities, the lowest level since 1975.³⁹ In comparison, Indian engineering colleges are graduating nearly twice as many engineers--over 115,000 each year.⁴⁰

Restructuring

U.S. Aerospace Mergers (15). Uncertainty: High; Impact: Moderate. Since the end of the Cold War, the U.S. defense industry has been in the midst of a sweeping consolidation defined by corporate mergers. However, the mergers may have hurt, rather than helped, the overall financial picture of the U.S. aerospace industry. Analysts trace the financial difficulties faced by many in the industry to mergers that created a corporate debt picture that, in turn, led to lower bond ratings.⁴¹

Nevertheless, mergers continue to occur within the industry. Analysts state that Loral Space & Communications Ltd faces pressure to find a strategic partner.⁴² Reports have surfaced that Loral and Lockheed-Martin are discussing possible ways to combine facilities and order backlogs. One rumored option envisions gradually closing Loral's satellite factory in northern California and transferring Loral's backlog to prop up Lockheed-Martin's order book.⁴³

European Aerospace Mergers (16). Uncertainty: Low; Impact: High. Consolidation has also occurred within the European aerospace industry. The multinational company Astrium was formed out of a merger between Daimler-Chrysler Aerospace (German) and Matra Marconi (French-British). It is expected that the Italian firm Alenia will join this group in the next phase of expansion. According to Dr. Klaus Ensslin, head of Astrium's Earth Observation and Space Business Division, "This merger was prompted by events in the United States. Astrium has the financial power which will allow us to take on projects with large dimensions and higher economical risks. It was time to react to the mergers in the American space industry."⁴⁴

Buyouts of U.S. Aerospace (17). Uncertainty: Low; Impact: Low. Orbcomm Global L.P., a subsidiary of the Orbital Sciences Corporation, has asked for bankruptcy court approval to begin an auction process to sell the business as a going concern. The early favorite to purchase Orbcomm was an Australian firm.

Market Dynamics

Apparent Direction Today: Demand for space-based information services has never been higher. All areas--communications, remote sensing, and navigation--continue to be in high demand throughout the world. A major exception to this has been the failure of Iridium and Globalstar to succeed in the global-mobile telephony market. This has dampened enthusiasm for the mobile services market throughout the satellite industry. Growth in commercial demand is being aided by the "dual use" characteristic of space. Defense departments and ministries are increasingly turning to commercial solutions to satisfy military requirements. New services are being developed from existing capabilities--witness the evolution of DirecTV to DirecPC. Launch gives the appearance of health, with the addition of multiple new launch vehicles and the development of several new spaceports. Yet, analysts predict that some launch service providers soon may be forced to abandon the market due to an over abundance of capacity.

Future Prospects: On the surface, demand for commercial space-based information services appears strong. The Europeans have decided to proceed with the development and deployment of their Galileo satellite navigation system. U.S. firms have received approval to increase the resolution of their next-generation commercial remote-sensing satellites to 0.5-meters. New ICO will offer global-mobile data services to users

in 2003. Nevertheless, unsettling questions remain about consumer demand for these new services--particularly communications. While some have hailed 1998 as a watershed event for commercial space (Recall that 1998 is the year commercial spending on space first surpassed that of the military), it may be a short-lived triumph. In the near-term, at least, military demand for space-based information services seems far more stable than commercial demand.

Relevance to Decision Focus: The strength of the commercial market for space-based information services has major implications for the Department of Defense. Neither existing nor planned DoD space systems can satisfy the military's demand for space. The U.S. military is counting on commercial space systems to meet a significant portion of its future requirements. U.S. space superiority, as it is currently envisioned, cannot be achieved without a healthy commercial market.

Remote Sensing

Demand for Remote Sensing Services (18). Uncertainty: High; Impact: High. Demand for timely, high-resolution, space-based remote sensing data continues to drive an expansion of the industry. In particular, new foreign-based imagery service providers not subject to U.S. "shutter control" laws are poised to join the market within the next three-to-five years. The addition of these firms will make it increasingly difficult to control the dissemination of commercial satellite imagery.

ImageSat International (ISI), a joint venture between U.S. and Israeli firms, is planning to launch a total of eight satellites by 2004. This project is significant in that this eight-satellite constellation will enable revisitation of ground sites on a worldwide basis more than twice daily.⁴⁵ ISI will sell its 0.82-meter resolution panchromatic

imagery and lower resolution multispectral imagery (MSI) over the Internet, enabling users to search for, order, and receive purchased imagery within a few hours of acquisition.⁴⁶

Astrium, a European aerospace consortium, completed a two-year long study that identified the need for high-resolution, commercially available, synthetic aperture radar (SAR) imagery. Astrium has proposed two "TerraSAR" radar satellites capable of providing 1.0-meter resolution imagery.⁴⁷ High-resolution SAR imagery provides all-weather, day/night, capability with obvious military applications.

RapidEye AG, a German firm, is planning to launch a constellation of four advanced electro-optic imaging minisatellites in 2002. These satellites will provide 6.5-meter MSI with a daily revisit capability.⁴⁸ What is significant about the RapidEye system is the fact that a constellation of minisatellites is being launched with the objective of providing timely imagery to users. Conceptually, this is very similar to the notion of a military "tactical imagery satellite."

Space Imaging Corporation, a U.S.-led joint venture, is the leader in the field of high-resolution commercial imagery. Space Imaging's Ikonos satellite was the first space-based platform to commercially offer submeter imagery. Now, Space Imaging has announced plans to launch a satellite in 2004 that will have 0.5-meter panchromatic resolution and 2.0-meter MSI resolution. As U.S. providers of high-resolution imagery continue to enhance their capabilities, experience has shown that foreign competitors will be forced to do the same.

In another development of note, firms are offering entire remote sensing systems--satellites, ground elements, and marketing networks--as a "turn-key operation." With

these packages, the satellite builders no longer retain interest in the service they provide, further complicating efforts to control the availability of high-resolution imagery.⁴⁹ Of particular concern are the sales of commercial-off-the-shelf (COTS) mobile vans. COTS mobile vans give a battlefield commander near-real-time (NRT) information and analysis. These mobile vans provide less-developed nations with valuable intelligence collection capabilities.⁵⁰

Communications

Demand for Communication Services (19). Uncertainty: High; Impact: High.

Demand for space-based communication services has undergone a significant change over the past decade. Customers are increasingly seeking individualized access to communication links like the Internet, not traditional services such as sending bundles of phone calls or television across long distances.⁵¹ The satellite industry has responded to the demand with new two-way technology that boosts the potential for widespread acceptance, but the question remains whether the time lag in entering the market will prevent satellite technology from dominating. Analysts predict both cable TV and digital subscriber lines (DSL) will already be entrenched, with cable having captured the residential users, and DSL the business users.⁵²

Demand for space-based communications services has been affected by the well-publicized failure of space systems such as Motorola's Iridium. The failure of Iridium affected consumer confidence about the stability of a service that requires an upfront investment of several hundred dollars for a handset.⁵³ The key lesson learned is that failure--or the appearance of--is transferable in the space industry and impacts the demand for related services.

The change in the market demand has forced providers of space-based communications to develop new, innovative approaches for attracting customers. For example, Lockheed Martin Intersputnik (LMI) is planning to mass-produce the Intersputnik standard small satellite bus and stock ready-for-use spacecraft and payload modules on orbit. LMI plans store these satellites in parking slots until they are purchased.⁵⁴

Pricing of Communication Services (20). Uncertainty: High; Impact: High. In order for space-based communication services to gain a significant share of the market, pricing must be competitive with similar terrestrial services. Prices for Iridium and Globalstar handsets and voice services were not competitive with terrestrial wireless. Now, it appears satellite Internet access is facing a similar dilemma. With customers paying between \$600 and \$1,000 to install a satellite dish and related equipment, some analysts do not believe the market for satellite Internet access is large enough to lower the price point to that of cable or DSL.⁵⁵ According to Jose Del Rosario, a strategic analyst at Frost and Sullivan, "The price points have to come down dramatically to entice people who reside on the other side of the divide. Currently, it's expensive relative to dial-up modems."⁵⁶

One approach some companies have taken is to combine Internet access with satellite television packages. For example, Hughes' DirecDuo service offers consumers both Internet access and programming from Direct TV.

Launch

Commercial Launch Supply--GEO (21). Uncertainty: Low; Impact: Moderate. A growing over-abundance of launch vehicles is leading the industry towards excess

capacity issues that can only be addressed by either explosive demand or, more likely, contraction of the service providers.⁵⁷

Commercial Launch Supply--LEO (22). Uncertainty: Low; Impact: Moderate.

Two trends are affecting the supply of launch vehicles available to place satellites into low-earth orbit. First, the Russian Federation has promoted the use of modified intercontinental ballistic missiles (ICBMs) such as the SS-18 ("Dnepr") for space launch. In accordance with the START-2 treaty, 150 SS-18 ICBMs are available for conversion to satellite launch vehicles through 31 December 2007.⁵⁸ The high reliability, large stockpile, and low cost of such launcher vehicles could have a major influence on the small satellite market.⁵⁹ In fact, on 26 September 2000, the Dnepr launched five small satellites into low-earth orbit, thus confirming the acceptability of the vehicle for this mission. It should be noted that the SS-18 is just one of several ICBMs the Russians have made available for commercial launch. The SS-19 and SS-25 have also been modified for satellite launches.

The second trend involves the development of special structures that allows secondary payloads to be launched with primary payloads on large boosters. The French have developed the Ariane Structure for Auxiliary Payloads (ASAP 5) that enables small satellites to be launched on the Ariane 5 vehicle. Using ASAP 5, it is possible to carry up to eight microsatellites into orbit along with the main payload.⁶⁰ The Indians have demonstrated a similar capability by simultaneously launching three satellites into low-earth orbit using their Polar Satellite Launch Vehicle (PSLV). These approaches are expected to cut the launch costs for small payloads considerably.

To provide additional flexibility for such “piggyback” launches, the U.S. firm AeroAstro has developed the small payload orbit transfer (SPORT) vehicle and the universal payload secondary interface (UPSI). SPORT allows launch vehicles to offer delivery to a specific orbit, even when a satellite is launched as a secondary payload.⁶¹

Commercial Launch Demand--GEO (23). Uncertainty: Moderate; Impact: High.

According to Bruce Middleton, Managing Director of Asia Pacific Aerospace Consultants Pty Ltd, the global capacity for launching commercial satellites will dwarf demand over the next ten years. This will result in heavy downward pressure on prices and may drive some players out of the market altogether.⁶²

Commercial Launch Demand--LEO (24). Uncertainty: Moderate; Impact:

Moderate. The demise of the Iridium, Globalstar, and Orbcomm, along with the downsizing of the Teledesic, has dampened the demand for low-earth orbit launch services. Particularly hard hit were a number of reusable launch vehicle concepts that promised to reduce the cost of space access.⁶³ Even launches of commercial satellites aboard converted Russian ICBMs are not expected to average more than four per year as once-high hopes for deploying constellations of telecommunication satellites to LEO have faded.⁶⁴

Financing

Apparent Direction Today: The *Space Industrial Base Study* has characterized the financial state of the U.S space industry as “poor.” According to the study, return on sales and return on assets are down; a good percentage of the major defense companies have bond ratings of BBB minus--just above junk bonds.⁶⁵ The deteriorating financial state has led, in turn, to low stock prices. Several well-publicized filings for bankruptcy

protection have also served to reduce investor enthusiasm for space. As a result, many companies in the industry are finding it extremely difficult to raise capital for future projects.

Future Prospects: Financing will remain tight until commercial space regains the confidence of investors burned by the poor performance of Iridium, Globalstar, and Orbcomm. The geosynchronous broadband satellites that will be launched within the next two years will provide the next major opportunity. Investors will be watching closely to determine whether these projects can succeed in the market. Much is riding on the success of these satellites--space-based communications cannot withstand another major failure. The industry will be buoyed, however, by the need to replace virtually the entire DoD space-based infrastructure within the next decade.

Relevance to Decision Focus: The availability of financing has a direct impact on the ability of the United States to maintain its technological supremacy in space. Lacking adequate sources of capital, the ability of the industry to start major new projects will be severely constrained. Companies will then look to cut costs--often at the expense of research and development. Leadership in technology has enabled the United States to gain space superiority; only continued leadership will allow the nation to maintain it.

Internal Sources

Independent Research and Development (IRAD) (25). Uncertainty: Moderate; Impact: High. Tight competition has forced aerospace corporations to cut costs. As a result, some firms have chosen not to invest their independent research and development (IRAD) money into innovative research and development projects.⁶⁶ According to General Moorman, this has two negative effects. First, it is innovative technology that

allows a company to stay ahead of its competition. Second, a company's reputation for innovative work (typically funded by IRAD) is what attracts young talent.⁶⁷

External Sources

Joint Ventures--Launch (26). Uncertainty: Low; Impact: Low. AeroAstro (U.S.) and Arianespace (European) have a cooperative agreement to develop a SPORT transfer vehicle compatible with the Ariane 5 "piggyback" system.⁶⁸

Consortia--Communications (27). Uncertainty: Low; Impact: High. International consortia have become the rule, rather than the exception, in space-based communications. There are several reasons why consortia have become popular--for example, desire to share costs and decrease exposure to risk, enter specific markets, and gain access to orbital slots. The following two examples are representative of the ongoing activity in this area.

LMI has established a joint project known as "Intersputnik-100M" that will produce up to 100 small satellites with C- and S-band transponders for use in geostationary orbit. In this partnership, Lockheed Martin provides advanced communications payload technology, while Intersputnik brings its reserved geostationary positions over the Atlantic Ocean and Eurasian landmass--a total of fifteen orbital slots.⁶⁹

In a significant break with past practice, the Indian Space Research Organization (ISRO) announced it would take the needs of private sector users into account in the design of future INSAT-series communications satellites. ISRO traditionally built satellites to its own specifications using government budget allocations. Now, the agency is planning to incorporate the requirements of commercial users--provided these users are willing to help pay for the spacecraft.⁷⁰

Joint Ventures--Remote Sensing (28). Uncertainty: Low; Impact: Moderate.

International joint ventures largely define the space-based remote sensing industry. For example, ImageSat International is a joint venture between Israel Aircraft Industries and the U.S. firm Core Software Technology. Even industry leaders, such as Spot Image (French) and Space Imaging Corporation (U.S.), have substantial foreign investment and participation.

Government and Private Sector Partnerships--Navigation (29). Uncertainty:

Moderate; Impact: High. In April 2001, the Europeans announced their decision to proceed with the Galileo satellite navigation system. When completed in 2007, Galileo will rival the U.S. GPS system. A partnership involving the European Union (EU), the European Space Agency (ESA) and European industry has been established to share costs throughout the life of the project. Initially, the EU and ESA will finance development and in orbit validation of the system. A mixture of public and private money will then be used to fund deployment of the constellation. Finally, industry will assume all operational costs after the initial operational capability (IOC) is achieved in 2007.

According to European sources, the impetus for Galileo was its guarantee of continuity of signal transmission.⁷¹ Galileo will provide Europeans with an independent system under civilian control that will be guaranteed to operate at all times. The Europeans were concerned that since GPS is financed and monitored by the U.S. military, the civil signal could be stopped or degraded at any time in the interest of U.S. national security.⁷² Galileo will allow Europe to acquire the technological independence it seeks in space-based navigation, as it has done with Ariane and Airbus.

Government Partnerships--Navigation (30). Uncertainty: High; Impact: High.

Joint operation of the GLONASS satellite navigation system continues to be a subject of discussion between Russia and China.⁷³ Due to financial difficulties, Russia has been unable to maintain a full constellation of twenty-four satellites. Russia would like for China to have a stake in the GLONASS project.

Government Partnerships--Remote Sensing (31). Uncertainty: Moderate; Impact:

High. A recent trend in this area has been for governments to establish multinational partnerships in order to offset the high cost of space-based remote sensing programs. Aside from saving money, such partnerships also facilitate the transfer of technology and expertise between nations. For example, China and Brazil are developing two remote sensing satellites under the "Satellite Sino-Brazilian Project of Land Resources" agreement.⁷⁴ China hopes the experience gleaned from operating the China-Brazil Earth Resources Satellite (CBERS) will support its efforts to develop improved military reconnaissance satellites.⁷⁵

France and Italy have agreed to work together to develop a remote sensing constellation. On 26 January 2001, the two nations signed an agreement to build six dual-use spacecraft--four radar satellites and two optical satellites.⁷⁶ Italy will build the four high-resolution (1-meter) radar satellites; France will build the two high-resolution optical satellites. Total program cost is estimated at \$924 million.

Venture Capital (32). Uncertainty: High; Impact: High. The well-publicized poor performance of several commercial LEO constellations has made it increasingly difficult for new and ongoing projects to raise the equity they need.⁷⁷ The fact that the Globalstar,

Iridium, and Orbcomm systems have all defaulted on debt has turned investors off to the industry in general.

Government Funding (33). Uncertainty: High; Impact: High. Government involvement in space can have both positive and negative consequences for the industry. An example of government involvement hurting the industry can be found in the case of Beal Aerospace Technologies (BAT). In 2000, BAT shut down its efforts to build a completely private medium-to-heavy lift rocket to launch commercial satellites into orbit. CEO of the firm, Mr. Andrew Beal, blamed NASA for his company's demise, stating: "There will never be a private launch industry as long as NASA and the U.S. government choose and subsidize launch systems."⁷⁸ Conversely, a positive instance of government involvement can be seen in the intervention to save the Iridium system. A guarantee potentially worth over \$250 million in government business was required to keep the constellation from being de-orbited. In this case, the government intervention bought time for a new management team to develop a self-sustaining user base.

Opportunities for Expansion

Apparent Direction Today: The concept of a global information infrastructure (GII) is being conceived on the basis of a vision of open connectivity and information access. The GII is envisioned as a "triad" of fiber, terrestrial wireless, and satellites where the means of communication is transparent to the user. Conventional wisdom holds that optical fiber will dominate the fixed, point-to-point market, terrestrial wireless will service the urban mobile market, and satellites will handle the rural mobile market.

Future Prospects: Space-based communications must gain a share of the market that provides high-speed Internet access to the home user. This is seen as a lucrative area

for satellites--provided they offer a service to consumers within the next three-to-four years. Traditionally, space-based services have been hurt by long lead times for development. By the time a space-based information service is ready for deployment, a terrestrial competitor is already well established in the targeted market.

Relevance to Decision Focus: Demand for commercial space-based services affects the overall health of the space industry. This industry is critical to the ability of the United States to maintain space superiority in the future.

National, Regional, and Global Information Infrastructure

Demand for Bandwidth (34). Uncertainty: High; Impact: High. The global demand for bandwidth will have a major impact on the overall health of the commercial space sector. Thus far, space-based communications have been very profitable for service providers. However, given what is happening in terms of bandwidth supply and demand, can this trend continue? In the Asia-Pacific region, for example, demand for bandwidth (driven by the Internet) may outstrip supply. Some analysts believe the region may be headed for a capacity shortage.⁷⁹ Yet, despite the bandwidth shortage, prices are steadily falling worldwide. Although bandwidth price is a function of supply and demand, rapid advances in optical networking technology are causing prices to drop.⁸⁰ There are those who believe this will eventually result in bandwidth being traded like a commodity.

Buildout of Terrestrial Optical Networks (35). Uncertainty: Moderate; Impact: High. Trying to predict the future of the fiber optic industry is difficult, yet necessary, if one is to assess its impact on space-based communications. Recall that providers of space-based communications are counting on the rural market for future growth

opportunities. However, one wonders whether the service providers are paying attention to the ongoing build-out of terrestrial optical networks. In the case of China, the telecommunications network already connects most Chinese cities and reaches into the thinly populated western provinces. China is also installing fiber optic equipment equivalent to a regional Baby Bell each year.⁸¹ On a global basis, Lucent estimates that if the growth of networks continues at its current pace, the world will have enough digital capacity by 2010 to give every man, woman, and child a connection of 100 Megabits per second.⁸²

Meanwhile, cable TV companies have recognized the need to make their systems bi-directional; many operators are in the process of upgrading much of their coaxial cable infrastructure with fiber.⁸³ Research and development also is continuing on the next stage of fiber optic technology--called ultradense wave division multiplexing--that will be able to multiplex hundreds of light waves. The radio frequency (RF) links used by space-based communications are already unable to keep pace with fiber data rates--this disadvantage will only increase in the future.

Space-Based Communication Networks--VSATs (36). Uncertainty: Moderate; Impact: High. Very small aperture terminal (VSAT) communication services have developed rapidly in recent years. VSATs enable nations to rapidly establish specialized networks throughout its territory. Large countries such as China have used VSATs to solve the problem of communications with remote areas. Over 80 networks have been built to support public and private functions like finance, meteorology, transportation, oil, water resources, civil aviation, power, public health, and the media.⁸⁴ VSAT services offer tremendous potential for military users. VSAT networks can be quickly set up in

austere environments and support C2 requirements for deployed forces. Worldwide, Hughes Network Services (U.S.) and Gilat Satellite Networks (Israel) are the two largest providers of VSAT equipment and services.

Integration of Terrestrial Optical Networks and Satellites (37). Uncertainty:

High; Impact: High. One of the keys to the future growth of space-based communications will be the ability of satellites to integrate with terrestrial optical networks. NASA, in cooperation with Japan's Communications Research Laboratory, conducted an experiment that demonstrated it is possible to effectively combine satellite and fiber optic cable links.⁸⁵ The space-based communications must continue to convince a skeptical market that satellites can handle data-intensive transmissions reliably and in conjunction with fiber.

Uncertainties

Commercial Demand for Broadband Satellites (38). Uncertainty: High; Impact:

High. The future of space-based communications is moving toward higher frequency, broadband satellites. These satellites will operate in the Ka-band (20/30 GHz) and promise downlink speeds on the order of tens of Megabits per second. In the United States, both Boeing and Lockheed-Martin are planning to launch broadband satellites. Boeing is taking a cautious approach to this market, choosing to deploy two Spaceway satellites (plus one on-orbit spare) over North America in late 2002. Lockheed-Martin Commercial Space Systems is also building a broadband constellation known as Astrolink. However, unlike Spaceway, Astrolink will debut as a global system.⁸⁶ It should be noted that not all space-based communication service providers are as confident about the broadband market as are Boeing and Lockheed-Martin. The

European direct broadcast satellite operator Societe Europeenne des Satellites (SES) has postponed by nearly a year its next-generation satellite system, saying early projections of a vast new market for satellite broadband services were too optimistic.⁸⁷

Research and development of broadband satellite communications technology is continuing throughout the world. NASA's Advanced Communications Technology Satellite (ACTS), launched in 1993, was the first satellite with the ability to carry digital communications at standard fiber-optic data rates with the same quality of transmission.⁸⁸ The ACTS program pioneered such technologies as dynamic hopping spot beams and advanced on-board traffic switching and processing. Now, both the Europeans and the Japanese are preparing to launch experimental broadband satellites of their own. The European ARTEMIS satellite and the Japanese "Gigabit Satellite" demonstrate that other nations also recognize the commercial potential of the broadband market.

Role of Satellites in the Internet (39). Uncertainty: High; Impact: High.

Providers of space-based communications services are focusing on the Internet as a key to future growth opportunities. The Carmel Group estimates that satellite service will capture ten percent of the U.S. high-speed Internet market by 2005, with more than 3 million subscribers.⁸⁹ Internationally, the potential could be even greater--particularly in those countries that do not have existing phone or cable lines in the ground to offer Internet service.⁹⁰

A handful of companies are behind an aggressive effort to use satellites to beam down Web pages. The international consortium New ICO, backed by cellular pioneer Craig McCaw, intends to launch commercial services in 2003. The goal is to provide global Internet protocol services, including Internet connectivity, data, video, voice, and

fax services to markets that are underserved by terrestrial communications services-- maritime, transportation, oil and gas, construction, and government agencies. Another company, Skycorp Inc., has signed an agreement with NASA to place the world's first Internet server in space. Skycorp Inc. will use its first satellite to test applications and refine wireless web technology for use in a future constellation of satellites.⁹¹

Global-Mobile Telephony via Satellites (40). Uncertainty: Low; Impact: Low.

The Iridium and Globalstar failures effectively ended the satellite industry's foray into the global-mobile telephony market. In reality, these systems were doomed to fail before they were even launched into orbit. The growth of terrestrial cellular phone service, available at a fraction of the cost of satellite phone services, did not leave a sufficient customer base for either service to break even, let alone make a profit.

The objective of Iridium and Globalstar was to offer consumers a single phone that would work anywhere on the globe. However, by the time both systems reached IOC, many cellular phone users could make calls across international boundaries as easily as between U.S. states. That left only the most rugged and isolated areas without cellular coverage, places where people do not have any money to buy such a service.⁹² It is worthwhile to note that the space-based broadband service providers are targeting essentially the same rural market. Given the performance of Iridium and Globalstar, one wonders whether they will be any more successful.

Competing Technologies

Resolution of the "Last Mile" Problem (41). Uncertainty: High; Impact: High.

The future growth of space-based communications hinges upon the ability of satellites to quickly position themselves as a competitive alternative to terrestrial options developed

to overcome the "last mile" problem. Since it is not cost effective to run fiber from the curbside to the home, DSL, cable modems, and satellites remain the only viable alternatives for providing high data rate Internet connections to single-family dwellings. In 2001, about 50 percent of broadband users get their high-speed Internet access through DSL, 25 percent through cable modems, and about 10 to 15 percent through fixed wireless technology.⁹³ According to Mr. Roland Van der Meer, general partner at Comventures, a venture capital firm that invests exclusively in communication technologies, about ten percent of this market is expected to be filled by satellites.⁹⁴

Optical Communications Developments (42). Uncertainty: High; Impact: High. Given the rate at which optical communications technology is advancing, one wonders whether the optical networks will become too fast for satellites to be effectively integrated. Engineers who have worked on experiments designed to demonstrate the integration of space-based communications with optical networks have noted the complexity of such projects. Connecting satellite systems to low latency terrestrial networks is truly a challenge.

Currently, fiber links can channel hundreds of thousands of times the bandwidth of microwave transmitters or satellites.⁹⁵ It is possible to send 160 frequencies, transferring data at a rate of 400 Gigabits (10^9 bits) per second, over a single fiber. In the future, data rates could reach as high as 300 or 400 Terabits (10^{12} bits) per second and perhaps exceed even the Petabit (10^{15} bits) per second barrier.⁹⁶ Optical switches are the critical missing link in building a superfast, all-optical terrestrial network. In existing fiber optic networks, the data contained in a wavelength of light must be broken up into slow-flowing data streams that can be converted to electrons for processing, then

“reaggregated” back into fast-flowing data streams. The equipment for going from photon to electron and back to photon not only slows traffic, but also causes equipment costs soar. Optical switching will bring about a fundamental shift in the design of telecommunications networks.⁹⁷

Dual-Use Systems

Defense Demand for High-Resolution Imagery (43). Uncertainty: Low; Impact: High. Senior U.S. military and intelligence officials have supported license requests from commercial firms to build higher resolution remote sensing satellites because they are eager to purchase the imagery in order to relieve some of the pressure on national capabilities.⁹⁸ According to the National Reconnaissance Office (NRO), on any given day, they cannot come close to fulfilling all the taskings they are given. Consequently, the U.S. intelligence community has become one of the largest customers of commercial satellite imagery. In fiscal year 2001, the National Imagery and Mapping Agency (NIMA) planned to buy \$35 million worth of commercial imagery and ground equipment for uses ranging from military operations to disaster relief.⁹⁹

Defense Demand for Broadband Communications (44). Uncertainty: Low; Impact: Moderate. A DoD task force chartered to estimate military communications needs for a “two major theater wars” scenario found that the total peak capacity required would exceed 35 Gigabits per second--almost 20 times what was used for the Bosnia operations in 1997.¹⁰⁰ This estimate far exceeds the total capacities of current and planned DoD communication systems, even when projected over the next decade.¹⁰¹ Exploding requirements for bandwidth have forced DoD to study how emerging

commercial communication satellite systems, fiber infrastructures, and mobile Internet technologies can be exploited to meet this demand.

Technology Proliferation

The proliferation of technology throughout the world--particularly microelectronics--promises to level the playing field in space. Key technologies have become so widespread that it is now possible for university graduate and undergraduate students to design, build, and fly relatively sophisticated microsattellites. Many of these "experimental" satellites are demonstrating capabilities once found only on satellites costing hundreds of millions of dollars.

Basic Research and Emerging Technologies

Apparent Direction Today: Much of the research being conducted today can be characterized as attempting to improve the cost effectiveness of space--engineers are succeeding in developing ways to increase the performance per kilogram of satellite. However, some of the research promises to truly revolutionize space operations. GPS space receivers, autonomous control, multifunction bus structures, hyperspectral sensors, and laser communications are but a few of the technologies currently being developed and tested.

Future Prospects: Most of the exciting, innovative research in space will involve small satellites weighing 100-kilograms or less. The ability of these small satellites to perform useful commercial tasks will increase as new operational concepts (e.g., formation flying) are demonstrated. In the absence of any major breakthroughs in

propulsion or materials technology, the reusable, single-stage-to-orbit (SSTO) launch vehicle remains unattainable.

Relevance to Decision Focus: The proliferation of space technology is extremely relevant to the U.S. ability to maintain space superiority in two respects. First, more nations will have access to space capabilities with some degree of military utility. Second, as the cost of access to space decreases, more nations will enter space. As the number of players in space increases, so to will their demand to have a voice in how space is governed. This can only lessen the ability of the United States to influence the environment.

Satellite Guidance and Navigation (G&N) Subsystem

Autonomous Rendezvous and On-Orbit Operations (45). Uncertainty: Moderate; Impact: High. Interest in developing satellites capable of autonomous on-orbit operations is growing in the United States and Japan. Such satellites would be extremely useful in the area of space logistics. In the United States, the Defense Advanced Research Programs Agency (DARPA) is developing an orbital refueling robot named the Autonomous Space Transporter and Robotic Orbiter (ASTRO). Potential operational uses of such a vehicle include on-orbit electronics upgrades, refueling, and reconfiguration of satellites.¹⁰²

In 1999, the Japanese demonstrated an autonomous rendezvous and docking capability in space with their ETS-VII satellite. Looking to the future, they hope to conduct robotic assembly operations at geosynchronous altitudes using this technology.

GPS Receivers for Guidance and Navigation (46). Uncertainty: Moderate; Impact: High. GPS receivers are now being used on board satellites for position and

attitude determination. The use of GPS space receivers makes the monitoring of satellites easier and cheaper for satellite operators.¹⁰³ The Europeans have been at the forefront of this activity with the development of two new GPS space receivers. ESA, in conjunction with the French firm Alcatel, has built a receiver designed for telecommunications and commercial remote sensing missions having strong reliability requirements. ESA has also collaborated with Surrey Satellite Technology Ltd (SSTL) of the United Kingdom on a receiver for the smallest type of satellites. Experimental and commercial missions have already been carried out for both receivers in low-earth and geosynchronous orbits.

Research is also continuing to improve the accuracy of GPS space receivers. The experimental Blackjack receiver, designed at NASA's Jet Propulsion Laboratory, was flown on German and Argentine microsatellites. The Blackjack receiver is reportedly able to continuously pinpoint the position of its host satellite with an accuracy of two-to-three centimeters.¹⁰⁴

Satellite Computers Subsystem

Onboard Computer Memory and Data Storage (47). Uncertainty: Moderate; Impact: High. The Air Force Research Laboratory (AFRL) announced a breakthrough in "phase change" allow materials that is expected to advance computer data storage capabilities. The technology may provide satellite computer designers with a low-cost, lightweight, low-power memory that will work reliably in any environment and will store data indefinitely with no power requirements or record data thousands of times a second for the life of the satellite.¹⁰⁵

Satellite Structures Subsystem

Lightweight, Multifunctional, Buses (48). Uncertainty: Moderate; Impact

Moderate. Lightweight, multifunctional buses offer the potential of increasing payload capacity by 25 to 35 percent while simultaneously lowering design, fabrication, and integration time. The concept integrates onboard sensors, instruments, and control functions directly into the structural material that comprises the satellite housing. The Multifunctional Structures Demonstration Experiment, a joint project between AFRL and Lockheed-Martin Astronautics, is being flown on a British research satellite in order to validate the technology.

Satellite Communications

Optical Intersatellite Communications (49). Uncertainty: Moderate; Impact:

High. Most advanced spacefaring nations--for example, United States, Europe, and Japan--have experimental programs underway to establish the key technologies necessary for optical crosslinks between satellites. Optical crosslinks offer distinct advantages over RF crosslinks in terms of higher data rates (tens of Megabits per second to Gigabits per second), larger communications capacity, and limited risk of interference with other communications systems.¹⁰⁶ Japan's Optical Inter-Orbit Communications Experiment (OICETS), Europe's Satellite Inter-link Experiment (SILEX), and the United States' Geosynchronous Lightweight Technology Experiment (GeoLITE) are intended to demonstrate optical communications in orbit, beginning in late 2001.

Optical Earth-to-Space Communications (50). Uncertainty: High; Impact: Low.

Japanese, European, and U.S. researchers are investigating optical links between ground stations and satellites. However, these links face a severe disadvantage due to the effects

of the atmosphere and weather. The first applications of these links are therefore likely to be seen in scientific satellites; as operational methodologies are developed, they will work their way into commercial systems.¹⁰⁷ Japan's OICETS will be one of the first satellites used to study the feasibility of optical links between an orbiting spacecraft and an optical ground station.¹⁰⁸

Satellite Remote Sensing

Medium Wavelength Infrared Imaging (51). Uncertainty: Moderate; Impact: Moderate. A medium wavelength infrared (MWIR) telescope flying on board a British research satellite achieved a world first by detecting a non-afterburning aircraft from space at an altitude of over 400 kilometers.¹⁰⁹ The aircraft was detected using only the heat created by the friction of flying through the air. The MWIR sensor is being used in additional tests to search for objects of military significance.

Hyperspectral Imaging (52). Uncertainty: Moderate; Impact: High. Hyperspectral imaging promises to be the next leap ahead in space-based remote sensing technology. Hyperspectral sensors use hundreds of very narrow wavelength bands to "see" reflected energy from objects on the ground. As a result, these sensors provide a much higher spectral resolution of a scene than is possible using other types of remote sensing technologies, such as multispectral imagers.¹¹⁰ Hyperspectral imagery holds tremendous promise in terms of military applications.

The Army is working to develop the image processing techniques necessary to exploit hyperspectral imagery. Army Research Laboratory has developed an algorithm that automatically classifies every pixel in a hyperspectral image by the type of material that it contains, using the spectral signature of that pixel and the information contained in

those adjacent to it.¹¹¹ The objective is to use the imagery to thwart adversary attempts at camouflage, concealment, and deception.

Small Satellite Developments (0.1 to 500 kg)

Apparent Direction Today: Small satellite missions are being made possible by taking full advantage of technological developments--the miniaturization of engineering components and the development of micro-technologies--for well-focused and small-scale scientific and Earth observation missions.

Future Prospects: Cooperative clusters or swarms of nanosatellites or picosatellites perform missions (e.g., communications; remote sensing) done by much larger spacecraft today. Small satellites will form themselves into virtual arrays or apertures optimized for specific tasks. Potential military applications include: on-orbit satellite inspection, antisatellite operations, and intelligence collection.

Relevance to Decision Focus: Small satellites make it very difficult, if not impossible, to maintain acceptable space situational awareness (SSA). Without a capability to acquire and maintain good "SA" throughout the environment, the concept of space superiority is a nonstarter.

Picosatellites (Weight: 0.1 to 1 kg)

State of Development--Picosatellites (53). Uncertainty: High; Impact: Low. The Aerospace Corporation successfully flew the smallest satellites ever placed into orbit. The picosatellites were only slightly larger than a deck of playing cards and weighed less than 275 grams. Ground controllers were able to transmit commands to the picosatellites, receive state of health data from the satellites, and monitor the status of the experimental

payload--in this case, an array of microelectromechanical systems (MEMS) RF switches.¹¹² The next two scheduled picosatellite flights will test a MEMS-based miniature inertial measurement and navigation component and a MEMS-based optical communications package.¹¹³ Additionally, Aerospace and AFRL announced plans to jointly develop a MEMS-based inspector picosatellite for launch in 2003.

Nanosatellites (Weight: 1 to 10 kg)

State of Development--Nanosatellites (54). Uncertainty: High; Impact: Moderate.

The University of Surrey, located in the United Kingdom, successfully flew the SNAP-1 nanosatellite and achieved the following "firsts" in small satellite technology.¹¹⁴

1. The first nanosatellite to use three-axis stabilization.
2. The first nanosatellite to utilize a propulsion system to perform orbit-changing firings.
3. The first spacecraft under 10 kg to take images of another spacecraft.
4. The first nanosatellite to successfully use the GPS system for orbital navigation.
5. The first nanosatellite to attempt an orbital rendezvous.

Proximity Operations Using Nanosatellites (55). Uncertainty: High; Impact:

Moderate. A British university is investigating the use of nanosatellites to perform satellite inspection missions. On 1 October 2000, the SNAP-1 nanosatellite, developed by the University of Surrey, provided "video telemetry" of its deployment off the mother satellite (see figure 6). According to Dr. Craig Underwood, SNAP-1 project manager, one of the primary objectives of the SNAP-1 mission was to demonstrate the ability of nanosatellites to act as robotic "eyes in the sky."¹¹⁵

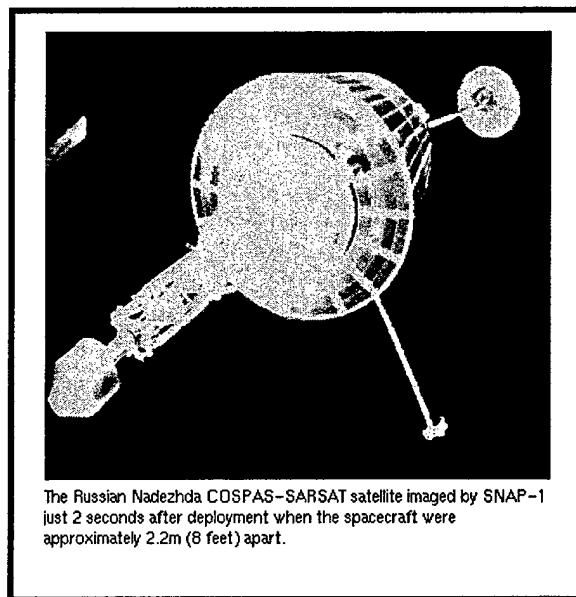


Figure 6. SNAP-1 Image of Deployment. Source: University of Surrey.

“Formation Flying” Using Nanosatellites (56). Uncertainty: High; Impact:

Moderate. In the future, collaborative clusters of interdependent nanosatellites, flying in close formations, may eventually circle the earth, replacing many of today’s single, larger satellites. DARPA envisions highly functional, individual nanosatellites that can operate in cooperative constellations, clusters, and on-demand swarms for communications and remote sensing.¹¹⁶ Such satellites would be lighter, less expensive to launch, offer more information gathering versatility to the war fighter.

AFRL is currently studying the concept of clusters of satellites that operate cooperatively. AFRL’s TechSat 21 project is intended to show how small satellites can share processing, communications, and payload functions. The key to this concept is a cluster of satellites orbiting in close formation.¹¹⁷ AFRL has contracted with the U.S. firm AeroAstro to develop a system for high-precision ranging and position

determination between satellites orbiting in precisely controlled formations. AeroAstro claims to have developed a system capable of determining relative position and range to centimeter accuracy or better.¹¹⁸ This is the critical technology that will facilitate formation flying and proximity operations.

Research into formation flying is also occurring at major U.S. universities. At the Massachusetts Institute of Technology, undergraduate students built three volleyball-size satellites to research, develop, and validate key formation flying technologies.¹¹⁹

Microsatellites (10 – 100 kg)

Applied Research--Remote Sensing Microsats (57). Uncertainty: Low; Impact: High. Microsatellite technology has moved beyond the basic research stage and is becoming more applications-oriented. In the United Kingdom, the Defense Evaluation and Research Agency (DERA) has contracted with SSTL to build a miniature, low-cost, imaging satellite. The goal of the Tactical Optical Satellite (TOS) project is to construct a 100-kilogram satellite with 2.5-meter panchromatic resolution and 5.0-meter multispectral resolution. The project aims to build a more affordable remote-sensing satellite by keeping camera development costs under \$5 million. Mr. John Ellis, one of the engineers involved in the project, believes bringing down the cost of the camera is essential if one wants to start flying constellations of imaging satellites.¹²⁰ According to those involved in the project, the Ministry of Defense wants to use the satellite to determine how the military could employ space assets with quicker response.¹²¹

The U.S. Air Force is also interested in developing military applications for microsatellites. At AFRL, the "XSS-series" of microsatellites will demonstrate a number of key technologies crucial to future operational missions. The XSS-10 microsatellite is

designed to demonstrate the ability to maneuver in space and park next to another satellite. While flying nearby, the satellite could do inspections, imaging, or search for damage on the other spacecraft.¹²² The follow-on satellite, XSS-11, will demonstrate advanced orbital maneuvers and station keeping; space surveillance of other objects is a key goal of this project.¹²³

Minisatellites (100 to 500 kg)

State of Development--Minisatellites (58). Uncertainty: Low; Impact: High.

China has been working on several small satellites projects with potential military applications. In fact, the People's Liberation Army daily has suggested that China could deploy a network of minisatellites for global reconnaissance. Both Tsinghua University and Harbin Institute of Technology are particularly active in the expanding field of minisatellites. Harbin is also developing the TS-1, said to be China's first domestically designed and developed microsatellite.¹²⁴ The TS-1 will have a resolution of 10-meters, which compares favorably to the French SPOT satellite. Tsinghua University has participated in a technology transfer program with the University of Surrey. In June 2000, the university, along with several high-tech companies, formed the Aerospace Tsinghua Satellite Technology with a focus on developing microsatellites and detector technologies.¹²⁵

Operations

Satellite Control Using Internet Protocol (59). Uncertainty: Moderate; Impact: High. In November 2000, NASA successfully demonstrated a TCP/IP-based architecture that could be used to enable trusted, distributed command and control of on-orbit assets.

In the near future, NASA will use standard Internet protocols for controlling and commanding experiments and operations aboard spacecraft from networked, remote ground locations using highly secure Internet connections.¹²⁶

Launch and Orbit Transfer Concepts

Aircraft-Assisted Launch to LEO (60). Uncertainty: Moderate; Impact: High.

Several nations are studying the feasibility of developing aircraft-assisted launch vehicles. The concept is not without precedent--the U.S. firm Orbital Sciences Corporation currently uses a modified L-1011 to assist its Pegasus launch vehicle. The primary attraction of this approach lies in its potential for a "launch on demand" capability from diverse launch locations.

The Israeli Ministry of Defense has provided Rafael Space Systems Director with seed money for preliminary feasibility studies involving aircraft-assisted launches of microsatellites. The concept involves using F-15 fighters to launch a variant of Rafael's Black Sparrow missile carrying military communications and signal intelligence microsatellites.¹²⁷

A Russian corporation, Vozdushny Start, is modifying four giant AN-124 transports for use as aircraft-assisted launch platforms. The company claims it will be able to deliver three-to-four tonnes into orbit with the aid of "Polyot" carrier rockets from any point on the Earth where at least a 10,000-foot runway exists.¹²⁸ At an estimated cost of \$1136 per pound, this would be one of the most inexpensive launch services available--roughly a tenth of the cost of Cape Canaveral launches and four times cheaper than Boeing's "Sea Launch" platform.¹²⁹ Vozdushny Start officials state they have three launches scheduled for 2003.

Dispensers and Transfer Vehicles (61). Uncertainty: Low; Impact: High.

Aerospace companies are beginning to offer orbit transfer vehicles specifically designed for small satellites. These vehicles provide a low-cost means for small satellites to reach “custom” orbits and will also increase the number of launch opportunities for these satellites on a variety of launchers.

AeroAstro is marketing a transfer stage designed to take small payloads from intermediate orbits to final ones. According to an AeroAstro press release, the Small Payload Orbit Transfer (SPORT) vehicle gives secondary payloads “the flexibility to achieve specific, tailored orbits not offered by the primary launch vehicle alone.”¹³⁰ The SPORT vehicle can perform orbit raising, orbit lowering, and plane change maneuvers. The vehicle is also advertised as reducing the total cost of dedicated access to space for microsatellites from about \$22 million to under \$10 million.¹³¹

AeroAstro has also developed a payload interface specifically for small satellites. The Universal Secondary Payload Interface (USPI) provides mechanical and electrical interfaces, a semi-standard payload envelope, and a universal adapter design intended for a number of launch vehicles--for example, Ariane 5, Delta II, evolved expendable launch vehicle (EELV), and the space shuttle.¹³² The objective is that a small satellite designed with USPI could be flown quickly and efficiently on any of the aforementioned launch vehicles.

Space Sciences Research

Research Using Commercial Satellites (62). Uncertainty: Moderate; Impact:

Moderate. Constellations of satellites provide a unique opportunity for researchers to obtain measurements simultaneously throughout the space environment. For example,

the Iridium satellites are providing scientists with continuous measurements of the magnetic fields above the Earth's poles. This is the first continuous monitoring of electric currents between space and the upper atmosphere and is generating the first maps of electric power flowing into the upper atmosphere.¹³³ Mr. Brian Anderson, a researcher at Johns Hopkins Applied Physics Laboratory, sees this leading to timely, accurate space weather forecasts that will give advance warning of electrical storms that tend to disrupt space-based information services.

Technology Transfer

Apparent Direction Today: There is now global availability of technology, over which no single country can acquire exclusive control.¹³⁴

Future Prospects: International commercialization of space will reduce the current U.S. edge in space support in civil, military, and intelligence activities.¹³⁵ Commercial and civil space services will offer both developing countries and nonstate adversaries access rivaling today's major space powers. Universities and their associated commercial entities will be a prime source of technology transfer.

Relevance to Decision Focus: The proliferation of space technology offers nations with no previous experience almost immediate access to space. This ability to "leapfrog" several generations of technology enables the emergence of competitors who may contest U.S. plans for space superiority.

Government-Sponsored Technology Transfer

Unmanned Space Technology Acquisition--China (63). Uncertainty: Low; Impact: High. Many countries have initiated aggressive technology transfer programs as

a means of improving their access to space. No nation has been as active in this area as China, with technical and economic cooperation and exchanges of different types in more than 70 countries and areas.¹³⁶ The Chinese realize that the rapid development of space technologies and applications worldwide poses a serious challenge for them. Therefore, they have initiated a development plan calling for a common satellite platform, a new generation of launchers, a combined satellite applications system, and the realization of the “space research and exploration project” by early in the twenty-first century.¹³⁷

China hopes to advance its own technology base by exploiting foreign commercial space developments. Recognizing that the design and technical performance of its satellites lags far behind that of western countries, China’s acquisition of foreign technology has been focused on systems and capabilities that would serve both economic as well as military clients.¹³⁸ During the research and development of its DFH-3 communication satellite, China had exchange programs with Germany, France, the United States, Italy, and Japan. China and Italy appear to be jointly working on a program to build “observation and data detection satellites.”¹³⁹ Additionally, China and Russian currently have eleven joint space projects underway.

Public statements from Chinese officials indicate these technology acquisition efforts will eventually pave the way for China’s own commercial space enterprises. Case in point: Tsinghua University has been receiving assistance from the University of Surrey on its microsatellite program. Tsinghua plans to run a commercial enterprise in the future, with the main revenue to come from the sale of microsatellites.¹⁴⁰

Unmanned Space Technology Acquisition--Turkey (64). Uncertainty: Low;
Impact: Low. Turkey’s efforts to develop an indigenous space capability are

representative of what has been occurring in other nations, such as the Republic of Korea and Taiwan. Turkey, in part, established the Turksat telecommunications satellite program to gain access to advanced space technology and enter the space industry. According to Mr. Enis Oksuz, Turkey's telecommunications minister: "What we [Turkey] are looking for is a real partnership that will generate business and promote training of qualified Turkish manpower. Turkey wants to be involved in the space industry."¹⁴¹

Manned Space Technology Acquisition--China/Russia (65). Uncertainty: Low; Impact: Moderate. Most foreign observers agree that China's manned space program is based largely on technology and expertise obtained from the Russians and the Ukrainians. In the mid-1990s, China purchased a Soyuz descent module from the Russians, as well as obsolete rendezvous and docking hardware from the Ukrainians. Chinese representatives have visited almost every major Russian center involved in the latter's manned space program. Russian space experts have also been invited to "give lectures" on space-related subjects in China.

Regional Space Cooperation--Asia (66). Uncertainty: Moderate; Impact: Low. There are signs that nations in the Asia-Pacific region are beginning to cooperate on space matters. In one instance, China, Iran, the Republic of Korea, Mongolia, Pakistan, and Thailand signed the "Memorandum of Understanding on Cooperation in Small, Multi-Mission Satellite [*sic*] and Related Activities." The purported intent of this agreement is to help enhance the progress of space technology and application in the Asia-Pacific region.¹⁴² Additionally, an Indian official stated that relations with China's space programs have improved recently.

Commercial-Driven Technology Transfer

Subsystem-Level--High-Resolution Electro-Optic Cameras (67). Uncertainty:

Low; Impact: Moderate. Israel's Ministry of Defense approved requests by Electro-Optic Industries Ltd to sell its Eros space camera to India.¹⁴³ The Eros camera, with a resolution of better than 1-meter, will be used on the Indian Cartosat-2 satellite.¹⁴⁴ Expected launch date of Cartosat-2 is in 2003.

System-Level--Small Satellite Design & Integration Skills (68). Uncertainty:

High; Impact: High. SSTL, associated with the University of Surrey in the United Kingdom, has one of the most extensive satellite technology transfer and training programs in the world. Surrey has trained over 70 engineers and graduated an additional 320 students from countries worldwide in its program in satellite communications engineering.¹⁴⁵ Table 10 provides a comprehensive list of nations SSTL has worked with since the mid-1980s.

Table 10. SSTL Technology Transfer Programs			
Country	Dates	Satellites	Organization
Pakistan	1985-89	BADR-1	Univ. of Surrey/SSTL
South Africa	1989-91	UoSAT-3/4/5	Univ. of Surrey/SSTL
South Korea	1990-94	KITSat-1/2	Univ. of Surrey/SSTL
Portugal	1993-94	PoSAT-1	Univ. of Surrey/SSTL
Chile	1995-97	FASat-Alfa/Bravo	Univ. of Surrey/SSTL
Thailand	1995-98	TMSAT-1	Univ. of Surrey/SSTL
Singapore	1995-99	Merlion Payload	Univ. of Surrey/SSTL
Malaysia	1996-98	TiungSAT-1	Univ. of Surrey/SSTL
China	1998-99	Tsinghua-1	Univ. of Surrey/SSTL
Turkey	1999-??	100-kg EO microsat	Univ. of Surrey/SSTL
Algeria	2000-02	Adv EO microsat	Univ. of Surrey/SSTL
Nigeria	2000-02	Nigeria Sat 1/2	Univ. of Surrey/SSTL
Egypt	2000-??	DesertSat	Italian Space Agency
Source: Surrey Satellite Technology, Ltd.			

Trade Policies and Export Controls

Apparent Direction Today: The most recent attempt to impose tight controls over the export of space technology may have caused irreparable harm to U.S. industry. Statistics indicate that orders for American-made satellites dropped after control over export decisions was transferred from the Department of Commerce to the Department of State. Meanwhile, orders for foreign satellites rose significantly. Although the United States has since eased up on its export controls, one questions whether American manufacturers will be able to earn this business back.

Future Prospects: Government efforts to control the transfer of space technology and services to potential adversaries will diminish. According to U.S. aerospace officials, export control efforts are often futile because most of the technology in U.S. commercial satellites is available from foreign competitors that do not have similar restrictions.¹⁴⁶

Relevance to Decision Focus: The task of maintaining space superiority has become much more difficult. Given the ineffectiveness of trade policies and export controls, it is more likely that the United States will face a space-capable adversary in the future.

Sanctions and Controls

Impact of National Space Programs on MTCR--Brazil (69). Uncertainty: Moderate; Impact: Moderate. Brazil joined the Missile Technology Control Regime (MTCR) after shifting control of its space program to civilians and signing treaties prohibiting the development of weapons of mass destruction. In 2000, the United States and Brazil reached a technical safeguards agreement allowing U.S. firms to launch American satellites from Brazil's Alcantara launch facility. Analysts believe the United

States intends to use its presence in Alcantara as a way to limit Brazilian attempts to acquire ballistic missile technology.¹⁴⁷ Yet, at 2.3 degrees south latitude, Alcantara is potentially one of the most flexible and cost-effective launch facilities in the world. Thus, the U.S. plan could prove difficult since companies and nations may be willing to trade technology related to ballistic missiles in exchange for launch rights in Alcantara.¹⁴⁸

Impact of MTCR on National Space Programs--India (70). Uncertainty:

Moderate; Impact: Low. India's failure to agree to the terms of the MTCR led the United States to impose sanctions on India, effectively banning American launch service providers from sending up Indian satellites. This led India to rely exclusively on Arianespace for launches to geostationary orbit. The United States also pressured the Russian Federation not to sell advanced cryogenic engines to the Indians. In spite of the sanctions, the Indians continued to develop ballistic missiles and space launch vehicles. The recent successful flight of India's Geosynchronous Satellite Launch Vehicle now eliminates Indian reliance on foreign launch providers.

"Shutter Control" of Imagery Satellites (71). Uncertainty: Low; Impact:

Moderate. The policy of "shutter control," as it relates to commercial imagery satellites, allows the U.S. government to shut down commercial satellites in the interest of national security, as well as any other time "international obligations or foreign policy interests may be compromised."¹⁴⁹ U.S.-issued licenses also contain provisions for the control of sensitive areas where space imaging might be limited, for example, U.S. companies can sell no better than 2-meter imagery of Israel.¹⁵⁰

The U.S. government approved requests from Space Imaging and EarthWatch to operate future satellites with 0.5-meter resolution. However, this next generation

imagery will only be available after a 24-hour delay from when the images are taken, a regulation established to alleviate concerns that foreign governments could use the photographs to conduct military operations against U.S. forces.¹⁵¹

Trade Laws and Restrictions

U.S. Export Law (72). Uncertainty: High; Impact: High. The spread of "dual-use" technology has rapidly increased since the end of the Cold War, making control vastly more difficult and practically impossible in a growing number of instances.¹⁵² The Export Administration Act of 2001 therefore attempts a narrower application of controls on "dual use" items. Stiffer criminal sanctions are probably the penalty exporters will have to pay in return for relaxation.¹⁵³

Impact of Export Restrictions (73). Uncertainty: Low; Impact: High. According to figures released by the Satellite Industry Association (SIA), in the nearly two years since Congress imposed additional export restrictions on commercial satellites, the U.S. share of the global market plummeted from 75 percent to 45 percent--an all-time low.¹⁵⁴ The SIA also concluded that U.S. commercial satellite makers lost \$1.2 billion in contracts and 1,000 jobs last year because of increased foreign competition and stiffer export controls.¹⁵⁵ California manufacturers of commercial geostationary satellites announced only 13 orders in 2000, down from 16 orders booked in 1998. At the same time, orders for European-made satellites increased to 16 from six.¹⁵⁶

U.S. satellite makers believe that having commercial satellites classified with tanks, missiles, and bombs resulted in time-consuming and expensive license delays and denials, which caused their customers to turn to suppliers in Europe. Mr. Gareth Chang, formerly head of international operations for Hughes, contends that U.S. satellite

manufacturers have lost credibility with foreign buyers, particularly in some of the world's fastest growing markets in Asia and the Middle East.

U.S. Quotas on Russian Launches (74). Uncertainty: Moderate; Impact:

Moderate. The United States no longer maintains an annual quota on Russian launches of American satellites. The quota, which was previously 20 launches per year, expired at the end of 2000. The decision clears the way for International Launch Services, a joint venture between Lockheed-Martin, Khrunichev Enterprises, and RSC Energia, to expand its satellite launch offerings in the U.S. space launch market. U.S. officials admitted they were concerned about the long-term viability of the joint U.S.-Russian venture had the quota continued.¹⁵⁷

Trade Environment

Telecommunications Regulatory Environment--Asia (75). Uncertainty: Low;

Impact: Moderate. Telecommunications analysts feel this is the first time in history that Asia-Pacific's regulatory environment is open enough for companies to invest on a pan-Asian basis.¹⁵⁸

Potential for "Buy European" Laws (76). Uncertainty: High; Impact: High.

Europeans were upset over U.S. decisions on export controls. European officials expressed their frustration with the situation, and called for a review of American export laws and practices in order to adapt their own legislation accordingly to "balance the situation." One report recommended that Europeans should declare a "European preference principle" for public procurement (i.e., a "buy European act") in order to favor and legitimize anchor tenancy practice.¹⁵⁹

Use of Space by Militaries

Militaries that do not use space are becoming the exception, rather than the rule. The last decade of the twentieth century clearly demonstrated the advantages of space to the terrestrial warfighter. Militaries are not only looking to use space to enhance the capabilities of their own forces, they are also planning to deny the use of space to their adversaries. The maturation of military space capabilities and doctrine will be a gradual process, but the trends, events, and developments observed over the past several years indicate many nations are already well along that path.

Incorporation of Space in Warfighting Doctrine and Force Structure

Apparent Direction Today: The use of space by military forces throughout the world is on the rise. The widespread availability of technology and services have lowered the cost of access to space for many nations. Additionally, there is a growing awareness that militarily useful data can be obtained from less than "state of the art" space systems. One study conducted by Sandia National Laboratories and the U.S. Army 250th military intelligence battalion demonstrated that medium resolution imagery (10-m panchromatic, 60-km x 60-km) could be used to detect, locate, and identify troop encampments in desert terrain.¹⁶⁰ The study concluded that a constellation of medium resolution microsats could be used as a troop monitoring resource for all Middle East, African, and Asian states that contain or border desert terrain. Another trend of note is the fact that denial and deception activities by foreign military forces are a growing problem as global awareness of U.S. intelligence capabilities improves.¹⁶¹

Future Prospects: Militaries will continue to acquire and integrate space capabilities into their force structures. There will be an increasing desire to purchase

“turn-key” systems. Nations will prefer operational control over space assets and will not be satisfied with merely purchasing space-based information services from vendors. Small satellites will enable individual countries to obtain completely independent communications, Earth observation, or defense capabilities at a rather low cost.¹⁶²

Relevance to Decision Focus: The United States is more likely to face a space-capable adversary. In order to maintain space superiority, the United States will need to develop offensive counterspace capabilities.

Military Doctrine for Space

Military Space Doctrine--China (77). Uncertainty: High; Impact: High. Chinese military strategists grasp the concept of space dominance. Writings and speeches by People’s Liberation Army (PLA) leadership acknowledge space as an essential dimension of regional warfare.¹⁶³ One paper written by two PLA senior colonels and published in the *Liberation Army Daily* acknowledged the critical connection between space warfare and information warfare.

In tomorrow’s war, information dominance will be critical. It will expand the implications of war, reach out to outer space because key information systems--space monitoring, positioning, and communication systems--will be deployed there.¹⁶⁴

Not to be left behind, China’s Air Force Academy has also recently increased the number of courses offered in space war theory.¹⁶⁵

It is likely China will seek to engage in three elements of space denial, that is, direct countering, tactically asymmetric responses, and denial and deception operations.¹⁶⁶ Denial and deception operations may be emphasized in the near-term, as China moves to strengthen its technological capabilities in other areas. A December

1999 article on PLA “anti-reconnaissance” exercises suggests there is a significant effort underway to develop countermeasures to satellites and other types of overhead monitoring.¹⁶⁷

Military Space Doctrine--European Union (78). Uncertainty: Low; Impact: Moderate. The creation of a rapid reaction force under the EU’s political responsibility has given the Europeans cause to think about an optimizing of their intelligence capabilities--to include space assets. The EU is looking at the exploitation of dual-use possibilities and the consolidation of Member state plans for communications, intelligence gathering, and observation satellites.¹⁶⁸

Military Space Doctrine--India (79). Uncertainty: Moderate; Impact: Moderate. The Indian military has recognized a shortfall in its space-based reconnaissance capabilities. The 5.8-meter resolution of current Indian remote sensing satellites (IRS-1C and D) does not permit the kind of real-time intelligence that the military requires.¹⁶⁹ Another problem the Indians face is a shortage of ISR assets. The ratio of information assets to ordnance assets within the Indian Army is one of the lowest in the world. In comparison to the U.S. ratio of 1:4, the Indian ratio is less than 1:20.¹⁷⁰ Operationally, this means the Indians have a preponderance of weapon platforms, but do not have matching capabilities in surveillance and target acquisition assets like satellites, UAVs, and gun locating radars.¹⁷¹

The Indians are looking to at least partially redress some of their reconnaissance shortfalls with the launch of Cartosat-2 in 2003. Cartosat-2 will have 1-meter resolution, providing the Indians with the precision they are looking for. In the meantime, the Indian

military will continue to use IRS-1C and IRS-1D to support major field exercises¹⁷² and real-world contingencies.

Also, in a sign that the Indian armed forces may be thinking about future space warfare, some officers have suggested that their high resolution reconnaissance satellites will need the ability to perform different orbital maneuvers, keeping in mind the hostile intentions of an enemy.¹⁷³

Military Space--Acquisition and Integration (A&I)

Military Space A&I--Canada (80). Uncertainty: Moderate; Impact: Moderate.

Canada's military is placing a high priority on improving its space-based reconnaissance capabilities. Canadian defense officials have announced plans to triple the amount of money spent on space research--with an emphasis on intelligence gathering and surveillance from space.¹⁷⁴

The current focal point of Canadian space-based reconnaissance activities is Radarsat-1, a "dual-use," synthetic aperture radar (SAR) imaging satellite with 8-meter resolution. Canadian defense forces have demonstrated the utility of this satellite as a maritime surveillance sensor, using it to observe war games on the east coast of the United States, as well as tracking ships.¹⁷⁵ In 2002, the Canadians will launch new SAR imaging satellite, Radarsat-2, with 3-meter resolution. According to Col Mark Aruja, director-general, joint forces development, the Canadian Forces wants to install a capability to track moving ground targets onboard Radarsat-2.¹⁷⁶ Finally, the Canadians are planning to launch Radarsat-3 in the 2005 time frame. A Department of National Defense report has identified "defense surveillance activities" as the number one application for this satellite.¹⁷⁷

Military Space A&I--China (81). Uncertainty: High; Impact: High. The Chinese military is aggressively incorporating all types of space-based information services within its military structure. The Chinese are using a mix of dedicated military satellites and “dual-use” commercial satellites to enhance their combat capabilities. Although Chinese space capabilities remain several generations behind that of most Western nations, the Chinese clearly understand the importance of space on the modern battlefield.

Communications. Mr. James Mulvenon, a Chinese military specialist with RAND Corporation, states the Chinese are involved in a “very, very robust effort” to upgrade their military communications systems to land-line fiber optics, digital microwave, and satellite communications.¹⁷⁸ The Chinese are also leasing transponder space on commercial communications satellites. China’s increasing reliance on internationally shared space platforms could complicate attempts to deny access to or destroy space systems used by the military forces.¹⁷⁹

Navigation. On 21 December 2000, with the successful launch of their second “Beidou” navigation test satellite, the Chinese completed the deployment of their first satellite navigation system. The new system covers all of China. The Chinese are now planning to build a second-generation satellite navigation and positioning system with more satellites and an expanded coverage area.¹⁸⁰

In addition to their indigenous system, the Chinese use the GPS network and are negotiating with the Russians to invest in their GLONASS system. For the Chinese military, however, GPS appears to be the system of choice. There are reports that the DF-21X intermediate-range ballistic missile as well as the DF-15 and M-11 Mod 1 short-range ballistic missiles incorporate GPS guidance packages.¹⁸¹

Remote Sensing. The PLA currently relies on an obsolete photoreconnaissance satellite as its primary means of overhead imagery collection. The Chinese are working to improve this situation with several ongoing projects. Reports indicate the Chinese are utilizing imagery from CBERS-1 for military applications. Although its resolution is poor, approximately 20-meters panchromatic, CBERS-1 is China's first satellite equipped with an electro-optic imaging payload. Xinhua, the Chinese news agency, has announced China will be putting up an eight-satellite constellation--four E-O satellites and four radar satellites--in the future.¹⁸² Not surprisingly, the Chinese have shown strong interest in Western radar satellite capabilities.¹⁸³

The Chinese are placing a high priority on the development of small satellites for defense applications. The PLA clearly understands the potential military implications of small satellites. In conjunction with small satellites, the Chinese are looking at launch concepts that would enable the rapid reconstitution of on-orbit capabilities. Chinese engineers are examining the utility of using mobile, solid-fueled space launch vehicles--such as a modified DF-21--or future variants of the DF-31 and DF-41; they also appear interested in satellite launches from transport aircraft.¹⁸⁴

Military Space A&I--Egypt (82). Uncertainty: Moderate; Impact: Low. Egypt, with Italian assistance, is planning to develop a satellite remote sensing capability to monitor the Middle East. Egyptian contracts with the Italian National Space Agency are the initial steps toward the creation of a full-scale space program.¹⁸⁵

Military Space A&I--France (83). Uncertainty: Moderate; Impact: Moderate. France has one of the leading military space programs in the world. The French have a high-resolution reconnaissance satellite (Helios), are considering the development of a

signals intelligence (SIGINT) satellite, and are a key participant in building the Galileo satellite navigation system. Additionally, the French Ministry of Defense has awarded Alcatel Space a contract valued at up to \$1.2 billion to build and launch between one and three military telecommunications satellites beginning in 2003. The "Syracuse-3A" satellite will provide French military forces with fixed and mobile communications systems and will be France's first dedicated military telecommunications satellite.¹⁸⁶

Military Space A&I--India (84). Uncertainty: Moderate; Impact: Moderate. India is one of the world's leading spacefaring nations with indigenous capabilities in launch, remote sensing, and communications. Although the Indian military has access to this technology, its incorporation within the armed forces has been constrained by resource limitations. This situation, however, may be changing as the result of lessons learned from 1999 military operations in the Kashmir. The Kargil conflict with Pakistan highlighted India's need for improved space-based remote sensing capabilities. As a result, India is aggressively moving to launch a high-resolution imagery satellite within the next three-to-four years. With the experience gained through designing, fabricating, launching, and successfully operating remote sensing satellites, the Indians are optimistic they will not find it difficult to construct such satellites for the exclusive use of the armed forces.¹⁸⁷

More significantly, the Indians have recognized that command, control, communications, computers, intelligence and interoperability (C4I2) systems, combined with surveillance and reconnaissance capabilities, have become inescapable for a modern military organization. Indian defense analysts are calling for the armed forces to work

out requirements and strategies for developing their own military network based on fiber optic cable and high-capacity satellite communications.¹⁸⁸

Military Space A&I--Italy (85). Uncertainty: Moderate; Impact: Low. The Italian Ministry of Defense uses nine transponders on board the Sicral-1 satellite for military communications.¹⁸⁹

Military Space A&I--Israel (86). Uncertainty: High; Impact: Moderate. The Israeli military is focusing on small satellites for its future defense needs. According to Major General Isaac Ben-Israel, the Israeli Ministry of Defense's director of defense research and development, the strategy is to build small satellites that will provide a sensible, relatively low-cost solution to military intelligence requirements.¹⁹⁰

Military Space A&I--Japan (87). Uncertainty: High; Impact: Moderate. Japan's military will develop a dedicated, space-based reconnaissance capability in response to a North Korean ballistic missile test which overflowed Japanese territory. Japan is planning to launch a total of four reconnaissance satellites--two high-resolution electro-optic satellites and two radar satellites--by March 2003.

Military Space A&I--Russia (88). Uncertainty: High; Impact: High. The military space forces bequeathed to the Russian Federation upon the collapse of the Soviet Union have fallen into a state of major disrepair and are not likely to be reconstituted. The Russians recognize that their economic difficulties caused them to miss an entire generation of spacecraft. However, this may have placed them in a better position to transition to the smaller, cheaper platforms of the next generation. In 2002, several Russian firms are planning to deploy microsatellites for optical and radar surveillance, missile attack warning, navigation, and communication.¹⁹¹

Military Space A&I--Turkey (89). Uncertainty: High; Impact: Low. The Turkish military has a requirement for high-resolution space-based imagery. In December 2000, the U.S. firm Space Imaging and Cukurova Holding/INTA of Ankara, formed an alliance to provide the Turkish armed forces with 1-meter resolution imagery from the Ikonos satellite.¹⁹² The agreement calls for Cukurova to build an Ikonos regional operations center that will be able to send tasking commands directly to the Ikonos satellite.

Military Space A&I--United Kingdom (90). Uncertainty: Moderate; Impact: Moderate. The British Ministry of Defense (MoD) has laid out its strategy for space. In the area of communications, commercial satellite communications will be used where appropriate. The MoD will focus available research and development funding on military-specific satellite communications requirements.¹⁹³ In the imaging field, the military will continue to secure the bulk of its imagery and geospatial data from "long-standing collaborative relationships." The MoD is also committed to developing the Tactical Optical Satellite (TOS) and will construct a mobile ground station to investigate the benefits of direct data reception in a tactical environment.¹⁹⁴ In navigation, although the MoD believes GPS is the most capable and cost effective option, it will keep its options open with respect to the European Galileo system.¹⁹⁵

Counterspace Capabilities

Apparent Direction Today: According to the Director of the Defense Intelligence Agency (DIA), Vice Admiral Thomas Wilson: "China and Russia have across-the-board [counterspace] programs under way, and other smaller states and non-state entities are pursuing more limited--though potentially effective--approaches."¹⁹⁶

Russia inherited a variety of counterspace systems and research and developments efforts from the former Soviet Union. In fact, Russia still retains among the world's most advanced and comprehensive counterspace capabilities, including the doctrine for its employment.¹⁹⁷ In Congressional testimony, Vice Admiral Wilson also stated that a number of other countries are experimenting with technologies that could be used to develop counterspace systems.

Future Prospects: DIA believes that by 2015, future adversaries will be able to employ a wider variety of means to disrupt, degrade, or defeat portions of the U.S. space support system. Weaker foreign militaries view U.S. space systems as a key vulnerability that could be exploited for a strategic advantage during a conflict.

Relevance to Decision Focus: If the United States is to maintain space superiority in the future, it must be able to protect its on-orbit capabilities against a growing counterspace threat. Protection may be the most important aspect of the United States' strategy for space superiority.

Space-Based Counterspace Systems

Space-based Lasers--Russia (91). Uncertainty: High; Impact: Low. As the United States continues to work toward a 2012 launch date for its prototype space-based laser, it is significant to note that similar work may have been conducted in the Soviet Union during the Cold War. In the mid-1970s, the Soviets were said to be working on a space-based laser ASAT weapon. Reportedly, NPO Energia was responsible for developing a laser cannon, known as "Skif-DM" for use against objects in LEO. The spacecraft was constructed and was ready for launch by 1987. However, just prior to the planned launch date, General Secretary Gorbachev announced that the arms race should

not be transferred into space.¹⁹⁸ It was subsequently decided not to carry out any experiments with the weapon.

Counterspace Microsatellites--China (92). Uncertainty: High; Impact: High.

Chinese writings indicate a significant interest in antisatellite warfare, an issue usually shrouded in extensive secrecy. On 5 January 2001, the Hong Kong newspaper *Sing Tao* reported on 5 January 2001 that China was planning to test an ASAT system in space "soon."¹⁹⁹ According to the article, the Small Satellite Research Institute of the Chinese Academy of Space Technology developed an ASAT weapon known as the "parasitic satellite." The reported operational concept was for the parasitic satellite to attach itself to an enemy's satellite and either interfere with or destroy that satellite.

The decision to develop the parasitic ASAT has both long- and short-term implications for the Chinese. In the long-term, the Chinese hope to establish a strategic balance between nations and break up the monopoly on the utilization of space that the superpowers hold.²⁰⁰ Short-term, the parasitic satellite would strengthen China's capabilities in controlling the usage of space globally.²⁰¹

Ground-Based Counterspace Systems

Satellite Tracking Networks (93). Uncertainty: Low; Impact: Moderate. The space situational awareness provided by ground-based surveillance networks is critical to successful counterspace operations. There are many relatively inexpensive technologies that can be used to detect and track satellites in LEO. The amateur astronomer community maintains orbital elements for most classified U.S. vehicles in LEO.²⁰² These orbital predictions are accurate enough that a country or other entity wishing to organize a camouflage, concealment, and deception (CC&D) effort against satellite reconnaissance

could do so. If a country wished to acquire a better LEO surveillance capability than amateurs possess, numerous commercial options are available.

Ground-Based Lasers--Russia (94). Uncertainty: High; Impact: High.

Unconfirmed, open source, reports indicate the Soviet Union may have conducted ASAT operations against U.S. reconnaissance satellites throughout the 1980s and early 1990s.²⁰³ According to a former Senate Intelligence Committee staffer, the Soviets regularly “pulsed” or targeted lasers on U.S. satellites. Unnamed Air Force officials were quoted by a United Press International correspondent as stating for years the Soviets had a “battle ready” ground-based laser at Sary Shagan that they believed had been involved in past blindings of U.S. spacecraft.²⁰⁴ Reportedly, as many as five ground-based laser sites may have been under construction in the Soviet Union at the time of its collapse.

Ground-Based GPS Jamming--Russia (95). Uncertainty: High; Impact: High. In 1997, a ground-based GPS jamming transmitter was being offered for sale at a Russian air show. The device was advertised as being capable of jamming GPS and GLONASS navigation signals within 200-kilometers of its location.²⁰⁵ The Russian firm Aviaconversia has apparently tried to sell this jammer in the Middle East.²⁰⁶

Ground-Based Interceptor Satellites--Russia (96). Uncertainty: Low; Impact: High. The Soviets began work on a ground-based interceptor satellite (see figure 7) in 1962. In August 1970, the interceptor successfully destroyed a target satellite with a fragmentation charge.²⁰⁷ The last test was staged in 1982; the program was reportedly terminated in 1983.

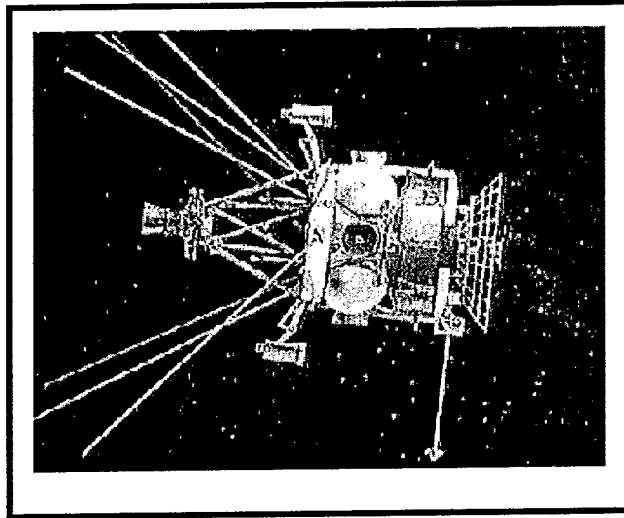


Figure 7. Soviet Interceptor Satellite

Ground-Based Jammers--China (97). Uncertainty: High; Impact: High. The Chinese probably have the technological capability to jam satellite uplinks or downlinks.²⁰⁸

Ground-Based Lasers--China (98). Uncertainty: High; Impact: High. According to unnamed U.S. intelligence officials, China is developing ground-based laser weapons that can blind or destroy U.S. satellites.²⁰⁹ Lasers are known to be a key area of investment for the Chinese military. The PLA envisions using lasers for satellite tracking, antisatellite operations, and radar functions. According to a DoD report, China may already have acquired foreign technology and technical assistance that could be applied to the development of laser radars used to track and image satellites.²¹⁰ The report goes on to say that the Chinese may possess the capability to damage, under specific conditions, optical sensors on satellites.

Cheap "On-Demand" Access to Space

Apparent Direction Today: It is expensive to launch a payload into space.

Consequently, the cost of access limits space missions to only the highest priority government missions and the most profitable commercial ventures. NASA was sponsoring development of the X-33 vehicle with the objective of decreasing costs and increasing safety and reliability. However, the X-33 was cancelled after an investment of nearly \$1.3 billion. The key lesson learned was that technology has not yet advanced to the point where a new reusable launch vehicle that substantially improves safety, reliability, and affordability can be developed.²¹¹

Future Prospects: The prospects for development of a single stage-to-orbit (SSTO) propulsion system within the next 10-to-15 years are not good. According to Air Force Lieutenant General Brian Arnold, Director of the Space and Missile Systems Center, SSTO is going to require "several miracles and a couple of inventions."²¹² With the recent fielding of several new expendable launch vehicles--Ariane 5 (Europe), Delta IV (U.S.) and Atlas V (U.S.)--the potential for innovation in launch is low.

Relevance to Decision Focus: The availability of cheap, on-demand, access to space has long been seen as a key element of the military's future in space. The ability to rapidly reconstitute space assets would significantly enhance the ability of the United States to maintain space superiority.

Conventional Propulsion Systems

Low-Cost Booster Engine (99). Uncertainty: Moderate; Impact: Low. The U.S. firm TRW has reported success in initial static fire tests of its low-cost booster engine project. The TRW engine features the least complex type of rocket propellant injector--a

single element coaxial pintle injector. TRW believes the low-cost pintle engine will cost 50-to-75 percent less than comparable liquid hydrogen boosters.²¹³

Actions of International Organizations

International organizations currently play a significant role in space, determining the allocation of frequencies, the assignment of orbital positions, and the allowable uses of space. As more nations gain access to space, the clout of the major space players within these international organizations could diminish. Now, some have gone so far as to recommend the formation of a U.N. Space Agency. Major spacefaring nations will need to recognize the agendas of the emerging players and take appropriate steps to ensure their "vital interests" are protected in these international forums.

Allocating RF Spectrum

Apparent Direction Today: Disputes between the terrestrial communications industry and the space industry continue regarding frequency allocation. Additionally, disputes exist within the satellite industry itself. In one case, a proposed LEO constellation posed an RF interference threat to GEO communications satellites until an innovative technical solution was developed. Finally, there have been issues between advanced nations and developing ones over the allocation of frequency. In summary, this is an extremely contentious area.

Future Prospects: Given the success of terrestrial wireless communications, that industry may see gains in frequency allocation at the expense of space. The ability of the United States to influence the direction of international organizations on the allocation of spectrum will continue to diminish. It is highly unlikely that the national security

interests of the United States will coincide with the economic interests of developing nations. The United States can expect to suffer an increasing number of setbacks in this area.

Relevance to Decision Focus: The United States must retain key portions of the electromagnetic spectrum in order to maintain space superiority in the future.

Spectrum Management

Harmonization of Frequency Allocations (100). Uncertainty: High; Impact: High.

The International Telecommunications Union (ITU) and other international forums are pushing to allocate the so-called “global-mobile” frequency bands identically in every country in a given region--even in every region. This is called “harmonization of allocations,” and while it would ease the problems associated with disparities among national allocations, it would hinder the ability of the United States to use unique, U.S.-only allocation arrangements to operate on a worldwide basis.²¹⁴

Competition for Frequency Use (101). Uncertainty: High; Impact: High. There is significant competition for RF spectrum between commercial and military users--as well as between strictly commercial users. The lower frequencies have the highest performance capabilities and are therefore in the greatest demand by mobile users. Consider, however, that approximately 90 percent of all military frequency assignments are in the bands below 3.1 GigaHertz.²¹⁵ According to Lieutenant General Harry Raduege Jr., head of the Defense Information Systems Agency, given the demand for global-mobile personal communications and the amount of capital involved, DoD will have a difficult time convincing authorities of its need for sole access to certain regions of the RF spectrum.²¹⁶

Competition within the commercial sector is just as keen. Firms in the terrestrial wireless industry have asked the Federal Communications Commission (FCC) to require companies that use geostationary satellites to prove they use their spectrum fully or else to share the frequencies with ground-based services. Representatives of the terrestrial communications industry claim the issue involves fair access to limited spectrum. The satellite industry opposes any changes, stating the proposal would dramatically impact the way satellite operators use the C- and Ku-band portions of the radio spectrum and would threaten projects intending to operate in the higher-frequency Ka- and V-bands.²¹⁷

Assigning Orbital Slots

Apparent Direction Today: There are increasing signs that developing countries will start to assert themselves more forcefully in space, demanding their “fair share” of space resources. The United Nations is currently encouraging ITU efforts to develop an efficient and more equitable distribution of frequency spectrum and orbital resources.²¹⁸ International organizations have become much more active in their management of orbital slots. Companies now must show tangible progress toward using the slots they are allotted or risk losing them to other parties.

Future Prospects: Pending developments in the demand for additional broadband communication satellites, the assignment of orbital slots will become much more challenging in the future. New players will demand access to slots that current owners are loath to give up.

Relevance to Decision Focus: Access to key orbital positions enables the United States to maintain space superiority.

Slot Management

“Paper Filings” of Orbital Slots (102). Uncertainty: High; Impact: Low. Many of the orbital locations in the “Clarke Belt” (GEO) remain unused and are at risk of being lost to U.S. satellite operators. Under the ITU, the United States could lose its priority rights if operational satellites are not deployed into these orbital locations by 2004. Representative Billy Tauzin (R-LA), chairman of the House Telecommunications Subcommittee, has urged the FCC to take slots from companies that are “sitting on spectrum and not using it.”²¹⁹

Governing the Use of Space

Apparent Direction Today: The world has seen considerable growth in the commercialization and privatization of space-related activities. The current body of space law was developed during an era when nearly all space activities were carried out by governments. Now, some are suggesting that the world needs to begin thinking about whether this existing body of law is adequate for the coming era of space commercialization.²²⁰

Future Prospects: Russia and China can be expected to try to constrain U.S. power through arms control--with the support of other U.N. members who resent the dominant U.S. position in the world.

Relevance to Decision Focus: International treaties that impose more restrictive conditions upon the use of space threaten the ability of the United States to maintain space superiority.

Existing Treaties

International Compliance with Space Laws (103). Uncertainty: Moderate;

Impact: Low. Many states have not yet become parties to the outer space treaties concluded within the framework of the United Nations. This decline in the willingness of states to bind themselves to the terms of successive treaties undermines the authority of the later international agreements. Additionally, adherence by states to provisions of treaties they have accepted is less than optimal.²²¹

Space Law Initiatives

United Nations Nonbinding Space Resolutions (104). Uncertainty: High; Impact:

High. The 54th Session of the U.N. General Assembly overwhelmingly adopted the "Resolution on the Prevention of an Arms Race in Outer Space." On a vote of 160-0 (the United States abstained), the delegates endorsed the nonbinding resolution calling for the banning weapons in space. The resolution petitioned those states with major space capabilities to contribute actively to the peaceful use of outer space and to refrain from actions contrary to that objective. The resolution further stressed that the negotiation of an international agreement on the prevention of an arms race in outer space remains the top priority of the Ad Hoc Committee of the Conference on Disarmament on the Prevention of an Arms Race in Outer Space. The resolution appealed to the Conference on Disarmament to immediately reestablish the Ad Hoc Committee with a mandate to negotiate a new international treaty on the prevention of an arms race in outer space.²²²

Efforts to Ban Weapons in Outer Space--Russian (105). Uncertainty: Moderate;

Impact: High. Russian President Vladimir Putin, in an address to world leaders attending the Millennium Summit at the United Nations, urged nations to hold an international

conference to ban weapons in outer space. President Putin described the 1972 ABM Treaty as a “foundation” of the entire nuclear arms control system and called plans for the militarization of space “particularly alarming.”²²³ Continuing on this theme at the Munich Conference on Security Policy, Mr. Sergei Ivanov, secretary of Russia’s security council, stated: “The destruction of the ABM Treaty will result in the annihilation of the whole structure of strategic stability and create prerequisites for a new arms race, including one in outer space.”²²⁴

Efforts to Ban Weapons in Outer Space--Chinese (106). Uncertainty: Low; Impact: High. At the Conference on Disarmament, China formally proposed negotiations to conclude a global treaty that would ban the testing, deployment, and use of weapons in outer space.²²⁵ The Chinese proposal was immediately backed by Russia. According to diplomats in attendance, the United States was the only member opposed to the establishment of a negotiating committee.

Launch Notification Agreement (107). Uncertainty: Low; Impact: Low. The United States and Russia signed a “Memorandum of Understanding on Missile Launch Notification.” The memorandum binds both parties to provide each other with pre- and post-launch notifications for launches of ballistic missiles. It also obliges the two parties, “with rare exceptions,” to give each other prelaunch and postlaunch notifications for launches of space launch vehicles.²²⁶

Global Space Utilities

International Use of GPS (108). Uncertainty: Low; Impact: Moderate. On 1 May 2000, President Clinton announced that the United States would stop the intentional

degradation (i.e., selective availability) of the GPS signals. Civilian users can now pinpoint locations up to ten times more accurately than they were previously able to do.²²⁷

Summary

This chapter represents a collection of the environmental forces that are driving the current space environment. Undoubtedly, there are significant forces that have been inadvertently omitted or overlooked. This is acceptable, in that no list of environmental forces will ever be completely all-inclusive. The forces identified by this research provide an adequate basis for the 2020 space scenario constructed in chapter 5.

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CHAPTER 5

ANALYSIS

Introduction

As evidenced by the number of events, trends, and developments identified in chapter 4, many forces are involved in shaping the future space environment. The challenge confronted here is to single out the “critical scenario drivers”--that is, forces having the most potential to significantly influence the future. These forces must then be molded into a coherent description of the future. A set of scenario rules or “logics” was developed in chapter 3 (see table 7) to assist and guide this process. The resulting scenario should provide a plausible future setting in which to evaluate the strategic concept of space superiority.

Working through the scenario development process is a useful exercise; however, the objective is to take the output from that process and use it to assess the current strategic concept of space superiority. This makes it necessary to apply the scenario in conjunction with a set of feasibility, acceptability, and suitability (FAS) evaluation criteria. Although the analysis will assess whether space superiority is a viable strategic concept within this particular alternative future, the most valuable result is likely to be the process itself.

Determination of Driving Forces

Driving forces were obtained by assessing environmental forces on level of impact and degree of uncertainty. The low/moderate/high scoring system employed generated a 3-by-3 “impact/uncertainty matrix” to capture all possible combinations.

Table 11 depicts the groupings of forces created by this approach. All of those environmental forces assessed “high” in both aspects were plotted in the upper right corner of the matrix. This area--referred to as the “area of uncertainty”--contains the required set of critical scenario drivers.

Extrapolation to 2020 Scenario

The United States emerged from the Cold War with superiority in space. The current concept of space superiority was largely formed out of that experience, as well as lessons learned from military operations conducted during the 1990s. Now, the question arises as to whether or not the United States can maintain that version of space superiority in the future. In order to address the issue, a scenario for the year 2020 is constructed based on an extrapolation of current forces. These forces were extrapolated by employing a set of scenario logics derived from the National Intelligence Council-directed *Global Trends 2015* study. For a more detailed discussion on how the scenario logics were developed, refer to chapter 3.

Scenario Assembly

The scenario assembly process begins by assigning critical scenario drivers to scenario logics. Some of the logics may be assigned more than one driver; others may be assigned none. Note that it is acceptable to use a driver multiple times. Next, based on an interpretation of scenario logics, critical scenario drivers are extrapolated to the year 2020. A key assumption made at this point is that the scenario logics represent accurate descriptions of tenets governing the 2020 time frame. This being true, driving forces will be affected in related manners (table 11).

Table 11. Environmental Forces Matrix

<ul style="list-style-type: none"> - Civil Unmanned Program--China (9) - Competition in the Global Marketplace (12) - Demographics--Retention and Retirement (14) - European Aerospace Mergers (16) - Consortia--Communications (27) - Defense Demand for High Resolution Imagery (43) - Applied Research--Remote Sensing Microsatellites (57) - State of Development--Minisatellites (58) - Dispensers and Transfer Vehicles (61) - Unmanned Space Technology Acquisition--China (63) - Impact of Export Restrictions (73) - Ground-based Interceptor Satellites--Russia (96) - Efforts to Ban Weapons in Outer Space--Chinese (106) 	<ul style="list-style-type: none"> - Civil Unmanned Program--Russia (10) - Commercial Launch Demand--GEO (23) - Independent Research and Development (IRAD) (25) - Government and Private Sector Partnerships--Navigation (29) - Government Partnerships--Remote Sensing (31) - Build-out of Terrestrial Optical Networks (35) - Space-Based Communication Networks--VSATs (36) - Autonomous Rendezvous & On-Orbit Operations (45) - GPS Receivers for Guidance & Navigation Subsystem (46) - On-board Computer Memory & Data Storage (47) - Optical Inter-satellite Communications (49) - Hyperspectral Imaging (52) - Satellite Control Using Internet Protocol (59) - Aircraft-assisted Launch to LEO (60) - Efforts to Ban Weapons in Outer Space--Russian (105) 	<ul style="list-style-type: none"> - Position on Militarization--Russian Leadership (1) - Position on Militarization--Chinese Leadership (2) - U.S. Opinion on Militarization (5) - International Opinion on Militarization (6) - Refocusing the Industry--Manufacturing to Services (11) - Demand for Remote Sensing Services (18) - Demand for Communication Services (19) - Pricing of Communication Services (20) - Government Partnerships--Navigation (30) - Venture Capital (32) - Government Funding (33) - Demand for Bandwidth (34) - Integration of Terrestrial Optical Networks & Satellites (37) - Commercial Demand for Broadband Satellites (38) - Role of Satellites in the Internet (39) - Resolution of the "Last Mile" Problem (41) - Optical Communications Developments (42) - System-level--Small Satellite Design & Integration Skills (68) - U.S. Export Law (72) - Potential for "Buy European" Laws (76) - Military Space Doctrine--China (77) - Military Space A&I--China (81) - Military Space A&I--Russia (88) - Counterspace Microsatellites--China (92) - Ground-based GPS Jamming--Russia (95) - Ground-based Jammers--China (97) - Ground-based Lasers--China (98) - Harmonization of Frequency Allocations (100) - Competition for Frequency Use (101) - United Nations Non-binding Space Resolutions (104)
<ul style="list-style-type: none"> - Position on Militarization--Chinese Media (4) - Civil Manned Program--China (8) - Commercial Launch Supply--GEO (21) - Commercial Launch Supply--LEO (22) - Joint Ventures--Remote Sensing (28) - Defense Demand for Broadband Communications (44) - Manned Space Technology Acquisition--China/Russia (65) - Subsystem-Level--High-Resolution Electro-Optic Cameras (67) - "Shutter Control" of Imagery Satellites (71) - Telecommunications Regulatory Environment--Asia (75) - Military Space Doctrine--European Union (78) - Satellite Tracking Networks (93) - International Use of GPS (108) 	<ul style="list-style-type: none"> - Position on Militarization--Indian Media (3) - Competition for Scientific & Engineering Talent (13) - Commercial Launch Demand--LEO (24) - Lightweight, Multifunctional Buses (48) - Medium Wavelength Infrared Imaging (51) - Research Using Commercial Satellites (62) - Impact of National Space Programs on MTCR--Brazil (69) - U.S. Quotas on Russian Launches (74) - Military Space Doctrine--India (79) - Military Space A&I--Canada (80) - Military Space A&I--France (83) - Military Space A&I--India (84) - Military Space A&I--United Kingdom (90) 	<ul style="list-style-type: none"> - U.S. Aerospace Mergers (15) - State of Development--Nanosatellites (54) - "Formation Flying" Using Nanosatellites (56) - Proximity Operations Using Nanosatellites (55) - Military Space A&I--Israel (86) - Military Space A&I--Japan (87)
<ul style="list-style-type: none"> - International Movement to Prevent Militarization (7) - Buy-outs of U.S. Aerospace (17) - Joint Ventures--Launch (26) - Global-Mobile Telephony via Satellites (40) - Unmanned Space Technology Acquisition--Turkey (64) - Launch Notification Agreement (107) 	<ul style="list-style-type: none"> - Regional Space Cooperation--Asia (66) - Impact of MTCR on National Space Programs--India (70) - Military Space A&I--Egypt (82) - Military Space A&I--Italy (85) - Low-Cost Booster Engine (99) - International Compliance with Space Laws (103) 	<ul style="list-style-type: none"> - Optical Earth-to-Space Communications (50) - State of Development--Picosatellites (53) - Military Space A&I--Turkey (89) - Space-based Lasers--Russia (91) - "Paper Filings" of Orbital Slots (102)

The following discussion: (1) restates each scenario logic (from table 7, chapter 3); (2) provides a synopsis of the new, extrapolated driver(s); and (3) references the applicable critical scenario drivers.

The United States will remain the dominant military power.

A majority of the American public supports a robust U.S. military presence in space, to include the deployment of weapons in space.

Based on an extrapolation of the following driving force(s): U.S. Opinion on Militarization (5).

Adversaries will pursue asymmetric capabilities against U.S. forces and interests.

See “counterspace capabilities.”

Adversaries will seek to attack U.S. military capabilities through electronic warfare, psyops, and denial and deception--primary purpose is to deny the United States information superiority.

All nations that are considered potential adversaries of the United States have developed both offensive and defensive counterspace (OCS and DCS) doctrine and exercise it on a regular basis. Most militaries have become so adept at camouflage, concealment, and deception activities that many sensors have been rendered obsolete for military applications.

Based on an extrapolation of the following driving force(s): Military Space Doctrine--China (77).

Probability that a missile armed with WMD would be used against U.S. forces or interests will continue to grow.

Based on an extrapolation of the following driving force(s): N/A. None of the driving forces directly correlate to this scenario logic.

International commercialization of space will give states and nonstate adversaries access rivaling today's space powers.

There is no longer an appreciable difference between military and commercial space capabilities. As a result, defense has become the single largest market for commercial space-based information services. All nations have access to high-resolution space-based imagery from a variety of sensors--visible, infrared, and radar. No less than three separate (but compatible) space-based navigation systems provide precise position and velocity data on a global basis. Commercial broadband satellites provide high-data rate communications to mobile users.

Based on an extrapolation of the following driving force(s): Demand for Remote Sensing Services (18); Government Partnerships--Navigation (30); Commercial Demand for Broadband Satellites (38); Military Space A&I--China (81); and Military Space A&I--Russia (88).

Several countries will have counterspace capabilities.

The military forces of most nations have operational counterspace units equipped with systems capable of jamming unprotected satellite communications and navigation signals. Many countries also have the capability to blind low-Earth orbiting remote sensing microsatellites. Most counterspace systems are still ground-based; however, the more advanced spacefaring nations have covertly deployed space-based weapons.

Based on an extrapolation of the following driving force(s): Counterspace Microsatellites--China (92); Ground-based Lasers--Russia (94); Ground-based GPS Jamming--Russia (95); Ground-based Jammers--China (97); and Ground-based Lasers--China (98).

More than 95 percent of the increase in world population will be in developing countries--nearly all in rapidly expanding urban areas.

See “population.”

By 2015, more than one-half of the world’s population will be urban.

The decreasing rural population base will reduce the size of a key target market for space-based communication services.

Based on an extrapolation of the following driving force(s): Although none of the driving forces directly correlate to this scenario logic, the logic itself has negative consequences for the future of commercial space.

Nonstate actors will play increasingly larger roles in both national and international affairs.

Global providers of information services will have international identities and financial backing; national origins of corporations will be largely forgotten. These international consortia will rely upon the universal availability of information services across traditional state boundaries for revenue; consequently, they will be motivated to exert influence at all levels in order to maintain this condition.

Based on an extrapolation of the following driving force(s): Refocusing the Industry--Manufacturing to Services (11).

Governments will have less and less control over flows of information across their borders.

Based on an extrapolation of the following driving force(s): N/A. None of the driving forces directly correlate to this scenario logic.

Globalization will increase the transparency of government decision-making.

Based on an extrapolation of the following driving force(s): N/A. None of the driving forces directly correlate to this scenario logic.

IT revolution represents the most significant global transformation since the Industrial Revolution.

“Intelligence” has shifted from the network to users at the periphery, causing bandwidth to be traded like a commodity (i.e., “bits/dollar”) rather than marketed as a service. International consortia offering “seamless bandwidth” will subsume formerly distinct corporations specializing in the provision of space-based communications services.

Based on an extrapolation of the following driving force(s): Refocusing the Industry--Manufacturing to Services (11); Demand for Bandwidth (34); and Developments in Optical Communications (42).

Prospect of universal wireless connectivity via hand-held devices; large numbers of low-cost, low-altitude satellites.

Low-earth orbiting (LEO) satellites are part of a seamless, global infrastructure that provides mobile, universal wireless connectivity to users. Due to advances in the design of highly capable microsatellites, large LEO constellations are now possible at a fraction of the cost of previous constellations (e.g., Iridium; Globalstar).

Based on an extrapolation of the following driving force(s): Demand for Communication Services (19) and Role of Satellites in the Internet (39).

Export control regimes and sanctions will be less effective because of the diffusion of technology.

Export controls and protectionist policies are no longer effective in the space industry. Technology transfer programs and offset arrangements (negotiated as part of previous satellite procurements) have led to the establishment of indigenous space industries in many countries. In fact, much of the world's satellite manufacturing capability now resides in those "second tier" nations where Western-educated engineering talent is less expensive and readily available.

Based on an extrapolation of the following driving force(s): System-Level--Small Satellite Design & Integration Skills (68); U.S. Export Law (72); and Potential for "Buy European" Laws (76).

IT will make major inroads in rural as well as urban areas around the world.

The price of space-based communications services remains far beyond the reach of people living in the rural areas of developing countries. In rural areas of developed countries where adequate demand exists, terrestrial wireless services are offered at prices lower than those available from space-based providers. Consequently, space has very limited opportunities for expansion in any rural markets.

Based on an extrapolation of the following driving force(s): Pricing of Communication Services (20).

Some states--adversaries and allies--will try at times to check what they see as American "hegemony."

Russian and Chinese leadership work in concert to build strong international opposition to any attempts by the United States to deploy weapons in space. This effort has culminated in the form of an international agreement banning all space-based weapons.

Based on an extrapolation of the following driving force(s): Position on Militarization--Russian Leadership (1); Position on Militarization--Chinese Leadership (2); and International Opinion on Militarization (6).

The United States will remain in the vanguard of the technological revolution.

The government funds most of the major research and development (R&D) activity in space, as venture capital is tied up in other more lucrative investment areas. Although a majority of R&D funding is committed to military programs, there is considerable spin-off to commercial projects. U.S. space technology is still considered to be the best in the world.

Based on an extrapolation of the following driving force(s): Venture Capital (32) and Government Funding (33).

Networked global economy will be driven by rapid and largely unrestricted flows of information.

A global information infrastructure (GII) of optical fiber, terrestrial wireless (i.e., cellular "data phones"), and satellites has emerged to move enormous quantities of data between nations, businesses, and individuals. Optical fiber cable connects most fixed users to the network; terrestrial wireless and satellites provide mobile users with access to

the optical backbone. Satellites move only a small percentage--perhaps less than less than five percent--of the overall information flowing across the network and are thus viewed as a relatively marginal player.

Based on an extrapolation of the following driving force(s): Demand for Bandwidth (34); Integration of Terrestrial Optical Networks and Satellites (37); Resolution of the “Last Mile” Problem (41); and Optical Communications Developments (42).

International or multilateral arrangements will increasingly be called upon to deal with growing transnational problems--to include the competition for scarce resources.

The United Nations has established the International Space Authority (ISA) to manage frequency allocations and assign orbital positions. The General Assembly has given the ISA a mandate to redistribute these limited space resources to developing nations. Unlike its predecessors, the ISA has been provided with effective enforcement powers.

Based on an extrapolation of the following driving force(s): Harmonization of Frequency Allocations (100); Competition for Frequency Use (101); and United Nations Non-binding Space Resolutions (104).

Scenario Elaboration

In aggregate form, the extrapolated critical scenario drivers become the 2020 scenario. Table 12 provides a summary of this scenario, entitled “Limited Horizons.”

Strategic Concept Viability

With the 2020 scenario available for use, the strategic concept of space superiority can now be evaluated. For the purposes of this research, the notional space superiority strategy found in table 1, chapter 1, will be utilized. Upon conclusion of the FAS evaluation, an overall finding on the viability of space superiority within the “Limited Horizons” scenario will be rendered (table 12).

Table 12. 2020 Scenario	
Title: “Limited Horizons” World	
Storyline: The commercial promise of space has long faded. Although space is ideally suited for military operations, it has found no equivalent “killer application” in the commercial sector. Thus military expenditures on space now again exceed those of the commercial sector. Space-based communications services are only a niche player in a global information infrastructure. Inexpensive mini/microsats with high-resolution sensors have decimated corporations that used to provide space-based imagery. Space-based navigation is the only sector that has seen expansion. Military forces in the “Limited Horizons” world continue to make extensive use of space-based services. Counterspace forces are now common to first and second tier militaries around the world. Although there is a treaty prohibiting the deployment of weapons in space, it is largely ignored (covertly) by those nations capable of constructing space-based antisatellite weapons.	
Table of Comparative Descriptions	
<ul style="list-style-type: none">• Nature of Conflict<ul style="list-style-type: none">➤ Most nations have operational counterspace units➤ Potential adversaries have developed OCS and DCS doctrine and exercise it on a regular basis➤ No distinction between “military space” and “commercial space”• Demographics<ul style="list-style-type: none">➤ Decreasing rural population decreases size of key market for space communications services➤ Price of satellite communications remains beyond the reach of people living in rural areas of developing countries• National & International Governance<ul style="list-style-type: none">➤ Universal availability of information services across national boundaries➤ International agreement banning the weapons in space	<ul style="list-style-type: none">• Science and Technology<ul style="list-style-type: none">➤ Satellite manufacturing capability now resides in “second tier” nations➤ Government funds most space R&D➤ Large LEO constellations of microsattellites• Role of United States<ul style="list-style-type: none">➤ American public supports a robust U.S. military presence in space• Global Economy & Globalization<ul style="list-style-type: none">➤ Bandwidth is traded like a commodity➤ Satellites service only a small percentage of the overall information flow on the GII➤ Defense is the single largest market for space-based information services• Natural Resources & Environment<ul style="list-style-type: none">➤ U.N. agency chartered to redistribute space resources

Assessing the Strategic Concept in 2020

In assessing the strategic concept of space superiority, it is important to note that some parts of the space superiority strategy may not be relevant to the “Limited Horizons” scenario. These parts will not be evaluated with the FAS criteria.

Evaluating the Strategic Concept Using FAS Criteria

The following discussion represents the evaluation of the strategic concept of space superiority using the FAS criteria. Each individual FAS-related question will be addressed and an overall (final) assessment will be provided based on those results.

In 2020, are sufficient resources to accomplish space superiority likely to be available?

NO. DoD resources are too thinly spread over too many competing priorities to maintain space superiority.

The failure of commercial space to secure a strong position in the 2020 GII has prevented DoD from leveraging commercial capabilities in any meaningful way. DoD has been forced to spend much more than anticipated to build and maintain its own dedicated, on-orbit capabilities. Nevertheless, a significant amount of military requirements remain unsatisfied.

Commercial investment in joint projects with the military is a thing of the past. Corporate investment in research and development is virtually non-existent. Venture capital has moved on to more attractive investment opportunities. Companies are loath to invest in space projects, given their historically low return on investment. Plus, with virtually no competition, there is little incentive to invest profits into research. Consequently, DoD must fund nearly all space R&D.

Given the 2020 space environment, is space superiority likely to be technically possible?

YES. Space superiority appears to be technically possible--given sufficient funding priority.

The technology to develop space-based situational awareness (SSA) capabilities, offensive space control capabilities, and space-based radar is readily available in the 2020 time frame. Remaining technology shortfalls are in space-based lasers and cost effective re-usable launchers.

Given the 2020 environment, is space superiority likely to be operationally achievable?

NO. There are too many operational challenges posed by the proliferation of small satellites and counterspace technologies.

The proliferation of highly capable small satellites with military applications has stressed ground-based SSA sensors. As a result, much of the SSA network has been migrating to space over the past decade. The need to search for--and track--small, maneuverable satellites is extremely stressing and can only be accomplished through an integrated, full spectrum, SSA network.

Given the proliferation of counterspace systems, it has become extremely difficult to protect space-based systems and services from attack. Particularly challenging is the threat posed by space-based antisatellite weapons.

Launch on demand is a viable concept given the availability of highly capable, inexpensive small satellites. However, with no major breakthroughs in re-usable launch technology, it remains an expensive proposition. Launch-on-demand is therefore available only for a limited number of critical systems.

Most military forces have significantly improved their camouflage, concealment, and deception (CC&D) capabilities. The reason for this improvement can be directly traced to an increased knowledge of the strengths and weaknesses of space brought about by widespread familiarity with space-based information services.

Given the environment, are there likely to be adverse consequences related to space superiority?

YES. There are likely to be adverse consequences if the decision to deploy a space-based missile defense system leads to a renunciation of the principle of “open skies” by other nations of the world.

If satellite overflights begin to be seen as the same light as aircraft overflights, serious challenges to strategic stability are posed.

Will space superiority be consistent with international law?

NO. China and Russia will continue to push for an international agreement banning weapons in space; they will likely succeed in their efforts.

Space superiority will depend on weapons in space. Yet, Russian and Chinese opposition to U.S. intentions to scrap the ABM treaty could have negative consequences for space superiority. If Russians and Chinese leaders preserve in their efforts to ban the deployment of weapons in space, much of the strategic concept of space superiority may not be in compliance with international law.

Is it possible that the cost--in terms of the instruments of power--of space superiority will become too high?

YES. The cost of space superiority will become too high in each of the instruments of power.

Economic Instrument. Without the deployment of a reusable launch vehicle, it will likely be too expensive to rapidly reconstitute constellations damaged by counterspace operations. However, it may be possible to reconstitute individual satellites systems on demand.

Military Instrument. The mission of protecting satellites from attacks by adversaries will stress the abilities of U.S. space forces. Counterspace technologies have become so readily available that most nations can field limited capabilities at the very least.

Political Instrument. Any unilateral decision to employ weapons in space--either for missile defense or counterspace--threatens to isolate the U.S. on the international scene. Yet, an unwillingness to do so undermines the concept of space superiority.

Information Instrument. See Political Instrument.

Is the attainment of space superiority likely to be compatible with other U.S. national security objectives?

YES and NO. If the United States is to remain a dominant world power, it must do so through the use of space superiority. Yet, if long-standing principles such as "open skies" are upset, that could harm U.S. security interests.

The United States will continue to rely upon the use of space to detect a first strike nuclear attack on U.S. territory, provide survivable C3I to expeditionary forces, detect indications of conventional attack globally, and collect technical intelligence data. As space superiority protects these objectives, attainment is extremely desirable.

However, if the deployment of weapons in space threatens any long-standing principles (for example, "open skies") that impact the aforementioned areas, then it becomes incompatible with national security objectives.

Is the current concept of space superiority likely to change before the year 2020?

NO. The concept of space superiority will likely remain grounded to "operational- and tactical-level force enhancement." The concept would significantly change if the United States moved to "space-based force application." Given the international situation, this is not likely prior to 2020.

Overall Assessment of Strategic Concept Viability

Analysis of the FAS-related questions leads one to the following conclusion: Evaluations of five criteria opposed the strategic concept of space superiority in 2020 while three criteria generally supported it. Consequently, this analysis finds that space superiority is not a viable strategic concept under a "Limited Horizons" scenario.

Summary

Although the concept of space superiority was not found to be viable for the time frame in question, the finding was extremely close. The analysis process primarily served to illustrate the complexities of the space environment. The most important knowledge to be gained is an awareness of all the diverse--and seemingly unrelated forces--that must be considered when assessing the viability of strategic concepts within a given space environment.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

Introduction

Space is emerging as the key enabler of the American way of war in the early twenty-first century. A CONUS-based expeditionary force characterized by “joint” combat units employing information, speed, stealth, mobility, and precision requires the use of space-based assets. Fortunately, the current generation of soldiers, sailors, airmen, and marines has been bequeathed a space environment in which the United States enjoys superiority over all other nations. The challenge of this generation--plus the ones to follow--is maintaining the U.S. advantage in space.

Thesis Question

This research effort set out to determine whether space superiority is a viable strategic concept through the *JV 2020* time frame. In the process of so doing, it became evident that space is an evolving operational medium that is affected by a complex interplay of economic, informational, military, and political factors. The ability to maintain superiority in space will always be vulnerable to changes in the geopolitical environment caused by these dynamic factors. Thus, in order to assess the viability of the strategic concept, it was necessary to construct a scenario for the 2020 time frame and then evaluate space superiority within that plausible future environment.

High Points

The most significant result to emerge from this research is not the evaluation of space superiority in 2020; rather, it is the development and demonstration of a methodology for assessing space strategy.

The scenario development process was very educational in terms of gaining an appreciation of the relationships between the “driving forces” associated with space superiority. Additionally, many “environmental forces” were identified that may have been overlooked had a less-structured methodology been followed.

Finally, the primary task to evaluate the viability of space superiority as a strategic concept necessitated that a strategy for space superiority be developed. Recall that every strategy incorporates not only a military strategic concept (ways), but resources (means) and military objectives (ends) as well. The process of “brainstorming” a notional strategy for space superiority in both the Cold War and post-Cold War time frames served to clarify how the emphasis in space has changed between the two eras.

Conclusion

The research methodology proved to be a capable tool. The integration of scenario learning with feasibility, acceptability, and suitability test criteria provides a way to evaluate space strategy within a future environment.

Findings

The important point to note about the analysis process is not the final assessment because that will almost certainly be proven incorrect by the passage of time. The key point is to become aware of all the diverse--and seemingly unrelated forces--that must be

considered when assessing the space environment. Space has come into its own as an area of responsibility, regardless of whether it is officially so designated by the Joint Staff. This analysis calls out the need for a cadre of space strategists who are schooled in the art of space strategy making.

New Knowledge

The literature review found that the scenario learning approach has been used previously to construct alternative futures for space. Air University's *Spacecast 2020* project developed eight unique scenarios, but (apparently) did not apply them to any particular problem(s). In this effort, scenario learning is used to develop a future scenario. However, that scenario is subsequently employed within an overarching methodology designed to assess a specific research question.

The use of the feasibility, acceptability, and suitability (FAS) criteria to test a notional space strategy is believed to be a "first." In joint doctrine, the FAS criteria are an accepted means of evaluating courses of action. The decision to apply FAS criteria in this methodology was deliberately done in an effort to "normalize" space with traditional practices.

Importance

The importance of this research lies in its ability to expand thinking about space beyond conventional paradigms. In terms of the primary question, the insight gained from working through the methodology leads one to conclude that the viability of space superiority may be determined more by commercial factors than military ones. For a

significant number of reasons--discussed in chapter 4--the commercial future of space is more tenuous than commonly believed.

Recommendation for Follow-On Research

Very early on in this project, it became evident that a "100 percent solution" would not be attainable on the first attempt. The following areas are therefore recommended for subsequent research.

Using Dr. Steven Metz' work in *Strategic Horizons*, additional future scenarios could be developed as a means of refining the overall methodology.

The set of 108 environmental forces that were identified in chapter 4 should be reassessed for accuracy; there may be cases where environmental forces could be consolidated, added, or deleted. Also, it may be possible to conduct some type of sensitivity analysis on the environmental forces. Those so inclined from an operational research perspective may find this challenging and interesting.

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